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THE CHIEF MECHANICAL INVENTORS OF LANCASHIRE.

INAUGURAL ADDRESS

OF THE PRESIDENT,

Mr. ALDERMAN W. H. BAILEY,

AT THE

GRAND HOTEL, MANCHESTER,

Saturday, 15th January, 1887.

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THE CHIEF MECHANICAL INVENTORS OF LANCASHIRE.

IMPORTANCE OF HISTORICAL KNOWLEDGE.

To bring before us the past, so as to enable us to understand, compare, value, and measure the present, and thus enoble and enrich the future, is the highest and should be the only function of history.

If we catalogue the accumulations of historical knowledge, and map out the sequence of events with their relation to each other, we introduce system and order in thinking; and by this useful mental discipline we carefully prepare the way for the legitimate exercise of critical and logical methods, which will enable us to sort out and condemn the false and the bad, to discover the true, the good, and the beautiful; but above all to give proper reasons for the opinions we hold. Obviously that which is true of universal history, is equally so when applied to the study of the historical development of any of the sciences, or of the mechanical arts.

This Society is increasing in numbers; we have now in its ranks many young engineers, all of whom owing to the conditions of membership, may, I think, be called captains of industry; certainly all are interested in the study of mechanical inventions. And I would say to these, that in my opinion, two primary qualities are required in all successful engineers, designers, or inventors of mechanical tools or new processes. The first quality is a thorough and complete knowledge of the history of the subject, and the second is the possession of a cultivated imagination. What is this historical knowledge? but that an engineer must have in his mind the rich records of the work of the

best, cleverest, and most successful men who have worked in the same direction as that in which he now is engaged. He informs himself of their difficulties, of their obstacles, of their mistakes and errors of judgment. He studies not only their best, but their worst work. He is enabled to see where the wise course has been successful, and why ignorance, idleness, or want of judgment led to failure; and thus by a few weeks' study of the literature of his subject, by this wise economy of mental force he obtains at a cheap rate the fruits of the toil, experience and brain work of a century.

CULTIVATION OF THE IMAGINATION.

The cultivation of the imagination, the art of seeing by the eyes of the mind, is the next great quality, but the materials used in the exercise of the imagination must be taken from the shelves of the historical storehouse, even as a builder uses bricks and mortar to erect a building.

There are other qualities, for it is true that "audacity is the first half of genius."

When to destroy the old before building up the new, when to be an Iconoclast, and when to venerate antiquity, when to neglect or to worship ancient gods, requires a fine sense of touch worthy of the Vicar of Bray.

The man who has broken "the cake of custom," who has dared to break away from the chains and fetters of his surroundings, who has destroyed the stereotyped conditions and had the pluck to pass the portals of the unknown, is often the man in history who has conferred upon the present and upon all future ages permanent blessings and endowments.

Of the Fine Arts the Sculptor I think is in most sympathy with the Engineer, for the ugly block of stone he works upon has within it divine possibilities when his hands and fingers have harmoniously obeyed the fine pentagraphic lines that are traced in the rich imagery of his brain.

Very few Poets admire the critical and logical faculty which is only the art of worshipping the best, of paying homage to the shrine of truth. The "Ode to a Grecian Urn" will live for ever and for ever, and be a delight to all who come after us.

Its author, Keats, says :—

"Do not all charms fly
"At a mere touch of cold philosophy,
"There was an awful rainbow once in heaven :
"We know her woof, her texture, she is given
"In the dull catalogue of common things."

In the dull catalogue of common things, and in the measure they minister to a man's needs, in the methods which give healthy bodies, and leisure, and contented calm, we find the standards that measure man's progress in civil life, for all authorities agree that it is not progress in poetry, in painting, in sculpture, or in the fine arts, in the cultivation of the beautiful, or in listening to sweet melodies ; but in the progress that man has made in the art of obtaining food, in finding out the divine uses of the earth, in capturing the rays of the sun, and bringing the warm mouth of heaven to kiss the earth, which in due time will yield to him its abundance. (Cheers.)

COUNTY OF LANCASTER.

"Lancashire is a county bordering on the Irish sea. The air "is generally wholesome, the earth fruitful (especially for breed-"ing cattle of large bodies) ; it is well furnished with fish, "flesh and fowl for food, with coals and turfs for fuel, with "mines, brooks and springs, and other conveniences," says an old chronicler.

WIGAN.

In the ancient days, the most important town for smiths and workers in metal was Wigan. Years ago here was carried on an extensive trade in wrought-iron ware, such as shovels and spades, frying-pans, Lancashire latches, wrought-iron hinges, nails, some of which yet exist in the neighbourhood of Ashton-in-Makerfield and throughout the district, including Chowbent and Warrington. I have heard the late Richard Roberts speak in the highest terms of some of the small tool makers of this district ; men who produce lathes whose beds are polished without the aid of planing machines, the filing-up being done by the use of 24in. files, one foot of the operator being in a sling to enable him, on tip toe, to have a good swing at his laborious

for in one of his letters to his son he tells him "to study the "history of great men and to avoid trumpery histories of miner-"alogy, geology, and such like gimcrack foolery."

It will be utterly imposible to treat of all the mechanical inventors of the county in one paper, and therefore with your permission the subject must be divided, I will call this the first part which we will together study in connection with a map which is now before us.

THE COTTON INDUSTRY.

The County of Lancaster is the seat of the cotton industry, and the great inventors of machinery for spinning and weaving displayed their skill here. The great invention of all, the very first that gave rise to all the succeeding inventions which have created the cotton manufacturing districts, was that of John Kay, of Bury. Before his time we had no superiority over the rest of the world, indeed the rude frames that were then used in this district were little better than those used at the present time in Central India and in the Pacific Islands.

JOHN KAY'S FLY SHUTTLE.

The mummy clothes of Egypt, the robes of Cleopatra, the tapestries of Rome, even the vestments of the Cavaliers, or the clothing of George the Second, were all spun and woven by simple tools, differing very little from each other; the distaff, the spinning wheel, and rude frames called looms, were the only methods known until the great invention of John Kay, who in the year 1733 invented the fly shuttle, which by means of a carriage on rollers, a piece of string and two pickers, enabled one man to do the work of four men. Dyer wrote about the old loom before this time, which when at work required for broad pieces two men, who threw the shuttle across to each other. He says:—

> "Or if the broader mantle to the task,
> He chooses some companion to his toil;
> From side to side with amicable aim,
> Each to the other darts the nimble bolt;
> While friendly converse, prompted by the work,
> Kindles improvement in the opening mind."

This invention of Kay's soon created a famine for yarn; the new looms could use up more weft, as it was called in those days, in half a day than the others could in four or five days. From the speed at which the shuttle could now be thrown and cloth formed, it obtained the name of the "Fly Shuttle." His patent was taken out in 1733. He was born at The Park, Walmersley, near Bury, and for a short time managed a Woollen Manufactury at Colchester. He invented a new method for making reeds for looms, and in his patents he styled himself "Reed Maker." He also invented a carding machine, and also one for twining and dressing thread.

In 1764 he wrote the Society of Arts, London, complaining of the bad treatment which he had received from the cotton and woollen manufacturers in different parts of England. His house was destroyed in 1753, and it was with difficulty that he escaped with his life. It has been said of Kay's loom, "it is "probable that no division of labour between the two hands of one "operative ever produced equal results to those obtained by this "invention" There is a model of the machine he invented for making wire cards in the Patent Museum at South Kensington. He died in obscurity and poverty in France and it is not known where he was buried.

SPINNING JENNY.

James Hargreaves of Blackburn, and Thomas Hayes of Leigh, both endeavoured to supply the great demand for yarn produced by Kay's new loom. I have devoted considerable time in examining the claims of both and I am inclined to think that the Spinning Jenny was invented by them simultaneously, indeed the Spinning Jenny appears to me what any member of this society might design if asked to convert the old spinning wheel into a machine for driving more spindles than one. Between 1766 and 1769, Hayes produced one with six spindles, and Hargreaves one with twelve, and they gradually enlarged the ıensions of the Spinning Jenny until the invention of ıg by rollers was introduced.

or, as he is called in some records, Highes, in 1767 pinning by rollers, but before that, Lewis Paul had

patented a machine in 1738. In this patent he says: "Cotton "or Wool being thus prepared is put between rollers or cylin- "ders, which being turned by other motion draws in the raw "cotton in proportion to the velocities given to the rollers, as "the cotton passes regularly or between these rollers, other "rollers moving proportionately faster than the first, draw the "sliver into any degree of fineness that may be required."

The art of spinning by the aid of rollers is here described for the first time. This idea was revived by Hayes, who employed a watchmaker at Warrington, named Kay, to make him a model, which had to be laid on one side because he had not sufficient capital to proceed with the invention.

ARKWRIGHT.

Richard Arkwright heard of this model and obtained another from the Warrington watchmaker, and by the exhibition of this to capitalists of Preston, Wigan, and other places, he was enabled to commence spinning by means of rollers, and took out a patent in 1775. In Arkwright's specification may be found described the Drawing Rollers patented by Lewis Paul in 1738, the Roving Can by Benjamin Buller, 1759, the Doffing Cylinder of James Watt, 1774, Crank for working the Doffer Comb invented by Hargreaves in 1772, a Fender for feeding the Cloth Carding Engine invented by John Law, 1772, and a Hammer for beating Flax, described in "Emerson's Mechanics," which Arkwright thought would do for beating cotton, but which in reality would simply destroy it; and about a page and half from an old encyclopœdia were all put into the specification, which was repealed by Act of Parliament in 1785.

The late Mr. Bennett Woodcroft, chief of the Patent Office, with whom I had some personal intercourse some years ago, was of opinion that if Arkwright was entitled to historical renown, it would be only as the inventor of the Factory System applied to cotton manufacture.

In 1770, Hargreaves exhibited a Double Jenny with twelve spindles on the Manchester Exchange, and became a man of some repute among the manufacturers of Lancashire. It was about this time that a testimonial was presented to him of 200 guineas.

The late Joseph Brotherton, the member for Salford, took a great interest in the daughters of Hargreaves, and I believe collected some money for them in 1822. Hargreaves died in poverty in the year 1788, at Nottingham.

CROMPTON'S MULE.

The next important inventor we find in Samuel Crompton, of Bolton, who was born in the year 1753, when all the new appliances for spinning had been found impossible to fill the mouth of the new loom, weft was used with such vigour that quite a famine in it was created; the spinners, either with the old spinning wheel or the new spinning jenny could not keep up the supply.

In the year 1777, Crompton invented the mule. "He erected," says Mr. Kennedy, "his spindles on a movable carriage, the "spindles turning on their axles or centres, whilst the movable "carriage resting on two beams or holders, which measure "out the rove to a certain length; two pairs of rollers were "used, made of wood, covered with sheepskin, having an axis "of iron on which the pulleys were fixed, one pair revolving "at higher speed than the other, this produces the draught or "elongation of three or four to one." This first machine had 48 spindles, one man with it could do an enormous amount of work.

In 1811 the government made him a grant of £5,000. Crompton had at one time to break up his machine and hide it, for his life was threatened. A Bolton minister warned his congregation against the breaking up of machinery and pointed out the benefit to be derived from new patents, one of the churchwardens, before the whole congregation, told the parson to mind his own business and stick to his text.

Crompton died in the year 1827, and in the year 1862 a fine monument in bronze was erected in Bolton, his native place, to commemorate his name as a public benefactor.

The next important inventors in connection with cotton machinery are those who coupled up the new steam engine with Kay's Loom and Crompton's Mule. The two great successors in this direction are Dr. Cartwright, a clergyman of Kent, and Richard Roberts, of Manchester. For a considerable time the Hand-

Mule of Crompton was the best spinning machine, but when the new steam engine of James Watt was coupled up to the loom, it so increased the production that another famine in yarn was again created similar to that which had existed after Kay had invented the Fly Shuttle.

This brings us to the name of Richard Roberts who invented the Self-acting Mule. Before giving an account of Roberts, let us notice what had been done in other fields of enterprise in the county.

A few words on the commercial geography of the cotton trade will enable us to comprehend the great changes that took place in the 18th century, it seems to me at the present moment that these changes should receive very thoughtful attention from those engaged in trade in this county, for that which has occurred before may take place again.

BARCELONA.

Barcelona was, in the middle of last century, the chief seat of the cotton trade, both for the raw material and for the manufactured article. Many Lancashire firms had warehouses in that ancient port, the firm of Peel having had offices there so recently as the end of the century. Cargoes of cotton for Lancashire consumption were landed at that port from the West Indies and America (the return cargoes consisting of slaves shipped from the African coast) and thence transhipped to Liverpool, there to be conveyed by road to its destination. The road traffic became so excessive that it led to the development of the Navigation of the Irwell, and the creation of the Bridgewater system. This direct communication of Manchester with the sea increased its importance, Bolton having, until this, occupied the more important position in the cotton trade, especially in yarns and the raw material. In course of time, the result of the work of Clarkson and Wilberforce on the one hand (making the slave trade illegal) and on the other, the direct connection of Manchester and the sea, coupled with the mechanical inventions for spinning and weaving and the use of steam power, Barcelona ceased to be a rival of Lancashire.

Eighty years ago, two large British ships a day entered the port of Barcelona, but forty years later not one vessel a week entered that port. Permit me to reiterate that the very commencement of our trade superiority was the invention of the Fly Shuttle, by John Kay, of Bury.

DUKE OF BRIDGEWATER.

It is claimed for the Duke of Bridgewater that he invented the Inclined Plane at Walkden, which was used for many years for lowering boats from one canal to another without the use of locks. The Rev. Mr. Egerton, in a paper read before the Society of Arts in the year 1800, claims this for him; but although I believe that Brindley's abilities have been very much over-rated as an inventor and contriver, and that the great enterprize of the Duke of Bridgewater has not had due acknowledgment, probably because of his high social position, which sometimes makes us forget the individual in the title, I do not think he is entitled to be considered the original inventor of the Inclined Plane, for such an arrangement was in use on the canals in China ages ago. The mechanical arrangements in connection with it he may have designed, and I have no doubt he did. Fulton, the American Engineer, gives Wm. Reynolds, of Ketley, credit for having constructed the first Inclined Plane, in his book on Canal Navigation, published in London, in the year 1796.

FIRST PRACTICAL STEAM BOAT.

Fulton was with the Duke of Bridgewater a considerable time before the year 1800, in this neighbourhood, and he here designed his first practical steam boat, worked with cranks and paddle wheels, in the year 1799, the one placed on the Hudson afterwards being a slight improvement on it.

The engine and boiler for this boat were made in Salford by Messrs. J. & T. Sherratt, of Foundry Street, the details of which will be found in a paper already read by me before this Society. Fulton's first Steam Boat being made in Lancashire entitled us to consider it a Lancashire invention.

FIRST IRON BOAT.

I have already described the work of Wilkinson in my last address to this Society. He made his first trade capital by the invention of the Box Iron, for ironing clothing and wearing apparel. He was born at Cartmel in a market cart. He was called the father of the Iron Trade; he invented and made the first iron boats, also was the inventor of an improved apparatus for boring cannon. He was the first man to bore an engine cylinder to the satisfaction of James Watt.

Wilkinson had to do with the design of the first Iron Bridge. He invented the Hot Blast, and introduced many improvements in the manufacture of iron.

In speaking of John Wilkinson's achievements in the manfacture of iron, it may be the members of the Society will remember that I called attention in my paper to the fact that he was the first to use James Watt's Steam Engine for rolling bars and sheets, and that he also drove his tilt hammers by means of the new power.

STEAM HAMMERS BEFORE NASMYTH'S.

I have carefully endeavoured to obtain evidence of the use of the direct acting Steam Hammer by Wilkinson, for when examining the history of the Steam Hammer in the year 1872, I wrote to the late Mr. Bennett Woodcroft to call his attention to the fact that the late Mr. William Dorning, of Manchester, had the Steam Hammer at work in Saxony before that invented by Nasmyth, of Patricroft. Mr. Woodcroft was kind enough to send me a specification of James Watt's, wherein he claims a direct acting Steam Hammer.

I believe however that James Watt, although he claimed it and suggested that a steam cylinder, with a hammer head upon a piston might be used for hammering purposes, there is no evidence to show that this was ever brought into practical use by him.

The Hammer invented by Mr. William Dorning was not at all equal to the beautiful mechanism in the valve arrangement, and general usefulness to the one invented by James Nasmyth,

for Dorning's was merely a cylinder fastened against the roof of the workshop, the piston of which lifted up the hammer by means of a chain and then let it fall. At some future time I hope to be able to give details of this early Steam Hammer.

NASMYTH'S STEAM HAMMER.

"I find there is not a forge hammer in England or Scotland "powerful enough to forge the paddle shaft of the engines for "the Great Britain," wrote Mr. Humphreys of the Great Western Steam Ship Company, to James Nasmyth of Patricroft, in 1838. This set Mr. Nasmyth thinking, and the story is so well told by Mr. Smiles that I will not occupy much time in dwelling upon it. It was some time after this before it was considered there would be a demand for steam hammers, in the meantime a Frenchman had seen Mr. Nasmyth's sketch and had constructed one a short time before one could be got to work at Patricroft, indeed it would have been impossible to construct many of our gigantic engineering works, engines, and machines, had not this useful workshop tool appeared at the right moment.

RICHARD ROBERTS.

Richard Roberts was born in the year 1789, at Llanymynech, North Wales, situated about six miles from Oswestry, and the same distance from Welshpool.

At the lead mines in the locality there were a number of Boulton and Watt's Engines at work, and it may be fairly supposed that a lad of such mechanical turn would be familiar with them.

The place which gave him birth furnished no longer the requisite scope for his energies, and he proceeded to the famous Barrowdale Iron Works, near Bilston, and worked for Mr. John Wilkinson. His occupation with Mr. Wilkinson was that of pattern-maker, at which he was very skilful and precise.

It cannot be doubted that Roberts would gain much valuable experience here, as well as at Horsley Iron Works, to where he moved next. He had to depart hence, however, to avoid arrest as a deserter, and this time he went to Liverpool where he ob-

tained employment as a cabinet-maker. He afterwards secured an engagement at Maudsley's works in London, and there can be no doubt that here, Roberts' mechanical skill and genius would have ample opportunity for development; his work was always beautifully exact.

Maudsley moreover, was the inventor of the Slide Rest for lathes, so that it would have been wonderful indeed if the talent of Roberts had not received great impetus from his contact with such a man. It is certain this was the school in which the young man received much of his best instruction, and not only he, for is it not alike remarkable that many other men who have become famous in the mechanical world mounted from the same works, and amongt these I may mention Whitworth, Nasmyth, Lewis, and Muir.

Roberts did not stay long in London, Manchester seemed to be the centre of attraction for all mechanicians at this time, and Roberts flowed with the stream towards Cottonopolis.

Roberts went to work in Manchester, when the field was wide and the time rich in opportunity. He invented a Wet Gas Meter at the request of the Town Commissioners of Manchester. Murdoch had fitted up Boulton and Watt's works with gas, and then went direct to Salford, and fitted up Phillips and Lowe's mill with the new light, afterwards the Manchester Gas Works was erected, and to regulate the amount charged for gas, this meter was invented.

The invention of the Slide Lathe at this period, placed a useful tool at the disposal of the mechanic and engineer, and the first one, designed by Roberts, is still at work, at Messrs. Beyer, Peacock's works, Gorton. The carriage of this lathe, instead of being on the top of the bed, was placed on the front, which enables it to take in a larger diameter than in the ordinary lathe.

There are many who claim to be the first inventors of the Slide Lathe. I have no doubt that as Maudsley invented the Slide Rest so any mechanic who had worked with it according to his needs, would develop the Slide Lathe.

Roberts is considered the inventor of the Planing Machine, which invention is claimed by Fox, of Derby. He also invented

a Slotting Machine with an automatic motion, and a Pentagraph Drilling Machine for drilling holes in objects without first centring the places. In 1822 and 1823, he took out a patent for weaving. The firm of Sharp and Roberts was then established as Tool Makers and Engineers. Mr. Sharp had bought a Patent for a Reed Making Machine with which he had considerable difficulty, but called in the aid of Roberts who could not make the machinery perfect, but said he could invent another better half the size to do the same work which he did, and they afterwards went into partnership.

Roberts afterwards became connected with the firm of Roberts, Fothergill and Dobinson, and then in his old age he conducted the business of a Consulting Engineer in London. In 1823, he patented improvements in steam engines, and also the mechanism in which the elastic force of steam was used to give impulse to regulate the speed of carriages. He patented the Regulating Valve for steam engines for cutting off the steam at any portion of the stroke, and his friend, Mr. Bennett Woodcroft, said that although working steam expansively was known long before his time, yet it is remarkable that Roberts was the first to take out a patent for it. He designed the first Locomotive made in Manchester, for the Dublin and Kingston Railway. The Locomotives afterwards made by Roberts had a great influence generally in improving their design, stability, and economical working, so much so, that even at the present day, modern Locomotives still bear in their outlines the impress of the genius of the old Manchester Mechanic.

One of his most wonderful inventions was the Jacquard Punching Machine, designed in the first case to punch the plates of the Britannia Tubular Bridge.

Tubular Bridges as is obvious consist of a number of plates exact duplicates of each other, and Roberts having been requested to design a machine, he produced such a one as enabled the plates to be placed against each other the holes coming exactly opposite, so that there was no difficulty in rivetting and making a good strong job.

Cards of any pattern could be put in the machine to regulate the pattern of the holes, just in the same way that cards are

used in designs for weaving in the Jacquard Loom. He patented improvements in clocks, timepieces, watches, improvements in electro magnets, in weaving, valves, water meters, pumps, evaporating apparatus, twin screw boats, ventilators, and anchors for vessels, paper and cardboard cutting machinery, omnibuses, engraving machines, and a host of other apparatus of which the enumeration of the catalogue would take more time than we have at our disposal. Roberts' greatest achievement however was the self acting mule, which he invented in 1825.

The Steam Looms, which had been invented by Dr. Cartwright, and improved by Horrocks, of Stockport, and other inventors caused such scarcity of yarn as to send up the wages of spinners, who worked fewer hours for increased pay. The manufacturers were hampered by continual strikes of those spinners, for they indeed had the whole trade in their hands, and could stop the mills when they thought proper by ceasing to supply weavers; dyers, bleachers and finishers, were all dependant upon twist.

A famine in Egypt is said to have led to the invention of the Pump, so necessity led to the invention of the Self-Acting Mule.

Several leading manufacturers waited upon Roberts, but he was busy with locomotives and tools then made by his firm, and had never devoted much attention to spinning machinery. At length, however, he directed a Crompton's Hand-Mule to be erected in the works, in order that he might familiarise himself with its motions, and make one that would work automatically. It is said that it took him 13 weeks to produce the first Self-Acting Mule, designing, pattern-making, and production, and in 1834 more than 60 mills, employing neary 60,000 spindles, had the invention at work.

The late Emperor of the French consulted Roberts about Armour Clads and Turret Ships, and I remember seeing the drawings submitted before they were taken to the Emperor, who received him in person.

The late Emperor Nicholas, of Russia, invited Roberts to live at St. Petersburg, but he declined.

During the American War of Secession, he designed the Twin Screws of the "Flora," which by means of independent screws could turn in her own length.

Roberts died on the 11th March, 1864.

POWER LOOM.

Now, as the crude idea of Dr. Cartwright's Steam Loom was very much improved upon by William Radcliffe of Stockport, and also by Horrocks of the same town, Radcliffe is entitled to the larger share of merit in the completion of the power loom than perhaps any other inventor. He was a man of original genius and an earnest politician and patriot. At a public meeting held in Stockport in the year 1800, he lectured those engaged in the cotton trade on the importance of division of labour, and he wrote a book of a curious and interesting character in which he gives reasons why the export of twist should be prohibited; he introduced valuable improvements in sizing and dressing cotton warps. He died in the year 1842 in his 81st year, and was buried in Mellor Churchyard.

FAIRBAIRN.

Sir William Fairbairn's life and works have received ample justice from Dr. William Pole; although it cannot be said that he was a great mechanical inventor, yet by his literary abilities, his love of knowledge for its own sake, his experiments involving the use of a high morality, his scientific investigations of truth, he has conferred great benefits upon not only the engineers of this district but upon all who use materials of construction. In 1831 he conducted elaborate experiments, and made some very valuable contributions to the knowledge of the co-efficients of force in connection with canal boat propulsion.

He was a civil as well as a mechanical engineer. He introduced improvements into Water Wheels, conducting extensive experiments on the strength of Wrought-Iron Plates, the Resistance of Railway Gradients, the relative power of Locomotive Engines, on the limited strength of Tubular Bridges, Boiler and Boiler Explosions, and on the mechanical properties of Metals after repeated meltings. His contributions to general literature of civil and mechanical engineering, in pamphlets, lectures, and papers, published in various ways, amount to about one hundred.

It was my good fortune to come in contact with him some years ago, and I dare say there are many in this room who

knew him well. He was a man of great shrewdness and pleasant manners.

Dr. DALTON.

Although Dr. Dalton was not a mechanical engineer, yet his various investigations were of such a character as to entitle him to be considered a mechanical inventor, as it has been said that he owed his great success as a chemist to his ingenuity in constructing his instruments for original work. Dr. Dalton was a Manchester man for the greater portion of his life. He taught Mathematics and Natural Philosophy in Faulkner Street in the year 1799, and apart from his contribution to the chemical science, his work has been of great value to engineers and manufacturers.

He published the Results of Experiments on the Power of Fluids to conduct Heat. He conducted experiments also on Steam Pressure, and the elasticity of vapour at all temperatures.

Dr. JOULE and Sir JOSEPH WHITWORTH.

In a similar way, as a mechanical inventor and physical investigator, we may class Dr. Joule, who would never have been able to conduct his experiments to success if it had not been for his ingenuity, as a contriver and mechanical inventor, for demonstrating and assisting him in the work in hand.

Dr. Joule was born in Salford, and is alive. His work commenced about the year 1840. His discovery of the mechanical equivalent of heat has given a greater impetus to the scientific treatment of the modern steam engine probably more enduring than that of any other living inventor or discoverer.

Sir Joseph Whitworth's contribution to the utility of mechanical tools and to workshop law I intend to treat upon at another time.

We have these two great leaders of men yet with us. Workers in different fields and true representatives of theory and practice, Dr. Joule discovering for us one of the laws of nature, of heat, force, motion, energy; and the other, Sir Joseph Whitworth, having given us standards of truth and fidelity in work, which has made his name a law in every workshop in the world.

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Professor Tyndall has described with some eloquence the great morality required in such work as that which has been done by these two great Manchester citizens. He says: "Those who are "unacquainted with the details of scientific investigation, have "no idea of the amount of labour expended on the determina-"tion of these numbers on which modern calculations or in-"ferences depend. They have no idea of the efficients shewn "by a Berzelius in determining atomic weights; by a Regnault "in determining expansion; or by a Joule in determining a "mechanical equivalent to heat. There is a morality brought "to bear upon such matters, which in point of severity is probably "without a parallel in any other domain of intellectual action."

Mr. Mulhall in his history of prices, says that the mechanical inventions of England enables six Englishmen to be equal to 24 Frenchmen or Germans, 32 Austrians, 50 Spaniards, 75 Italians, or 84 Portuguese. Energy costs in England 36 °/₀ less than on the Continent, and that we have sufficient machines to fight the hostile tariffs of any continental nation. Five English men can now accomplish as much as six in 1870 or as eight in 1850. Steam power is increasing at a rate which adds to our force eighty million foot tons daily.

I have endeavoured to tell the story of the work of Lancashire men (often poor) who have enriched the world. Let their names be enshrined in a green spot in your memories. If public benefactors were permitted to pass away without commemoration and without gratitude, genius and enterprise would be deprived of their most coveted distinctions, sense of personal value would be blunted, and those who come after us would lose incentives to that emulation of our forefathers which, when existing, makes a man not only of value to himself, but also a blessing to the whole community. (Cheers.)

VOTE OF THANKS.

Mr. Thomas Ashbury said the usages of the Association did not permit of any criticism on the Address, therefore they were debarred from alluding to many interesting points; however there was one duty which remained to them, and that was to express to the President their thanks for the treat he had given them that evening. Lancashire might certainly be considered the home of inventors, as he had no doubt if the records of the Patent Office were searched it would be found that no other county in the United Kingdom had so many contributors to its records as that of Lancashire. The site on which that meeting was then held was almost classic ground in engineering, it being within a very few yards of the places where once stood the works of Richard Roberts, Nasmith and that of Bennet, the agent of James Watt. The indomitable perseverance which was characteristic of Lancashire men had doubtless a great deal to do with the remarkable number of inventors in that county, and this characteristic was supplemented by another which might be expressed in the word accuracy, and which was so faithfully exemplified in the life and works of Sir Joseph Whitworth. If as Lancashire engineers they were to maintain their superiority amidst the great multiplicity of inventions at home and abroad, they must continue to devote thorough conscientiousness to the work they had in hand; whether the work they had to do was large or small let them follow the example of the old Lancashire men, by having about it conscientiousness and accuracy in every detail of its execution.

Mr. Ashbury then briefly advocated the adoption of some kind of a memorial to Richard Roberts, the great Lancashire inventor, which he believed, if inaugurated by the Association, would be generously supported by the public generally, and in concluding said he had great pleasure in proposing that they convey to the

President their best thanks for the interesting and lucid address which he had given them, and for the gratifying indications which he had also shewn to them that they would be further favoured on a future occasion.

Mr. R. Rawlinson in seconding the resolution, said he was sure they had all listened with attention and interest to the President's elaborate and searching address, and which had certainly added to their information regarding their own locality. Mr. Rawlinson then briefly alluded to the works of Sir Wm. Fairbairn, whose genius he said was most conspicious in the "Tubular Bridge," and who in his opinion might fairly be styled the "Father of Tubular Bridges and Girders." It was not only by applying themselves to their work as they had done in the past, but it was essential that there should be more education and more technical training amongst the workmen of this country, if they were to put themselves in a position to meet the strong competition which was growing up against them in every part of the world.

Mr. E. Asquith supported the resolution.

The resolution was passed with acclamation.

The President suitably acknowledged the vote and the proceedings terminated.

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THE MANCHESTER ASSOCIATION OF ENGINEERS
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1856.

THE THERMO-DYNAMIC ANALYSIS OF THE STEAM ENGINE.

A PAPER

READ BY

MR. H. GUTHRIE,

(Member of the Association,)

ON 29TH JANUARY, 1887,

AT THE GRAND HOTEL, MANCHESTER,

Mr. THOMAS ASHBURY, C.E., Past-President,

IN THE CHAIR.

MANCHESTER:
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1887.

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THE THERMO-DYNAMIC ANALYSIS OF THE STEAM ENGINE.

On the occasion of Mr. Dixon's paper of last Session on the "Conservation of Energy," I remarked that I thought it would be very interesting and instructive to this Society if Mr. Dixon or some other gentleman would put before us some complete analysis of the energy spent in machinery; after which I felt somewhat committed to offer my own shoulder to the wheel in order to bring about what I myself so urgently recommended; hence the present effort. The subject is of extreme interest to me, and I sincerely hope that I may be able, as I go along, to so warm your interest in the matter as to generate a hot discussion.

In Thermo-Dynamic Analysis, of course, there is an enormous field to work in; but I only propose, this evening, that we should direct our attention to that still almost universal generator of power, the Steam Engine.

But what is a Steam Engine? Well, of course, every member of this society should know what a steam engine is: at the same time there is a degree of indefiniteness about the term which it is necessary we should clear up, so that we may understand one another as to the exact limits of the steam engine, for the purpose of this paper. We must have the complete apparatus for liberating the potential energy of the fuel, converting it into power, and distributing or directing that power as may be required. Taking this more comprehensive conception of the steam engine, we must include all the apparatus between the furnace door on the one hand, and the chimney top, exhaust pipe, and fly-wheel or belt pulley, on the other hand.

The diagram before you represents such an apparatus, and it will now be my duty to explain this diagram and show you the why and the wherefore of its different parts. The diameters or widths of all its channels are drawn to scale, and represent foot-pounds, and where admissible, I have also represented heat units. And so, now as I think we understand one another as to

the terms we are to proceed on, I will immediately proceed with the analysis proper.

For convenience then we will confine ourselves, as is the custom with all analysts, to one unit only, that unit being *one pound of coal.*

The potential energy or calorific power of one pound of coal is commonly taken at 13,000 heat units (13,006 heat units were obtained as an average of 97 experiments by Government officials). That is to say, one pound of coal contains sufficient potential energy to raise the temperature of 13,000lbs. of water 1° Fah., or, 1lb. of water 13,000° Fah. If then we multiply this by the mechanical equivalent of heat given to us by Joule, we have 13,000 units × 772 foot-pounds = 10,036,000 ft.-lbs. as the potential mechanical equivalent of 1lb. of coal, and this is the basis scale of my diagram, as you may see by glancing at the maximum width across the furnace portion. And now let us light up and see how much of this potential energy we can develope.

Of course, we all know that combustion is a purely chemical process, and as chemical elements only combine in definite proportions, we should know exactly how much oxygen, and therefore air, is required to burn one pound of coal. The mean analysis of the 97 kinds referred to is given as follows :—

	lbs.	Proportion of Oxygen required.	Combining weights.	Oxygen required in lbs.		The combination producing
Carbon ..	·8040	× 2 ×	16 ÷ 12 =	2·144	CO_2 =	Carbonic Acid
Hydrogen ..	·0519	× ·5 ×	16 ÷ 1 =	·4152	H_2O =	Hydric Oxide or Water
		Less Oxygen present		·0787		
Oxygen ..	·0787			·3365		
Nitrogen and Sulphur	·0246		say	·0195	=	Sulphurous and Nitric Acid
Ashes	·0408					
	1·0000			2.5000		

I have taken this analysis as I got it; but personally, I should have preferred to have shewn the available hydrogen by itself,

joining the necessary portion for the oxygen with that element and calling it water; however, in our case, it is of little importance; we are not going to quarrel about a few units of heat, though it may be well to note in passing, that if the oxygen in the fuel is in the form of water it is not only not available to produce, but is a positive bain in absorbing heat. This matter of water in fuel and in the ashpit would be a fruitful subject for discourse, but we must not stay for this to-night, but press on the generally accepted lines. We must likewise pass over the nitrogenous and sulphurous elements of our fuel, which may have a great deal to do with the waste and pitting of boiler plates, such as has been depicted only lately by our friend Mr. Boswell, who might possibly be able to tell us that by the practice of a wet ashpan, we only supply the necessary water to the products of combustion to precipitate the harmless dry sulphurous and nitrous acids into the most destructive and corrosive moist acids which get safely capilarated between the brickwork and the plates, to do all the destruction they can. To proceed then we require chemically (some men would say theoretically) 2·5lbs. of oxygen to combine with the elements of the fuel.

We know air is composed of

23·16	parts	of	Oxygen
and 76·84	„	„	Nitrogen
100·00	„	„	Air.

therefore the ratio of oxygen to air is $\frac{100\cdot00}{23\cdot16} = 4\cdot3178$ which $\times$ 2·5 = 10·79lbs. of air, and which at a temperature of 62° Fah. there are 13·14 cubic feet to the pound, 10·79 $\times$ 13·14 = 142 cubic feet chemically required for the complete combustion of the fuel. I have just made the remark that some men would say that this quantity was required theoretically. You must therefore pardon a few moments digression in order that I may explain myself and free that much abused word, on this occasion at least, of its illegitimate use. It is a common expression, "Oh, it is all very well in theory, but it wont do in practice." Now, I say, a (so called) theory which is not practical, is not a theory worthy the name, but only

For the purpose of this paper, we may ignore the iron plates between the furnace and the water, and suppose the heat to be transferred direct. We are told, and I think it is accepted as a general practice, that only 75 per cent. of the heat generated passes through the plates to the water, so, taking this proportion we will proceed to calculate the amount of steam which would be generated in absorbing it. Now the average specific heat of water between 60° and 212° is 1·007. Therefore 212 − 62 = 150 × 1·007 = 151·05 heat units required to raise 1lb. of water to boiling point. Add to this the latent heat of water and we have 1117·05 units required to evaporate 1lb. of water from 62°; dividing 75 per cent. of the 13,000 units—that is to say, 9,750 by 1117·05, we find we can evaporate 8·7283lbs. of water, (the vapour from which weighs 27·4156 feet per lb.) = 239·29 cubic feet, which, if we again multiply by the pressure of the atmosphere 2116·2 per □ ft., we get 506,385 foot-pounds of work done in expanding to steam. And now, gentlemen, as we shall not come across a more remarkable difference in the whole of our analysis, I must ask you to take particular notice, that, in order to be able to deal with what we are accustomed to look upon as the more convenient elastic gas called steam, we are content to accept 20 per cent. and throw away 80 per cent. of the energy developed in the furnace, for this is as nearly as possible the proportion of the figures we have produced. I have now an almost uncontrollable desire to run off upon the theme of gas and caloric engines, to show the absurdity of some hundred or so of patentees who have greatly elaborated their schemes in order to improve their efficiency by adding water to evaporate to steam and assist and increase the expansion of the other dry gases in use; whereas, as a matter of fact, for every foot of steam they introduce, they lose about four feet of the other dry gases or create a balance to the bad of three feet. It may be a very good thing to introduce air into a steam boiler, for then the tables will be turned and there will be a positive gain; but steam or water must never be associated with the charge of an air or gas engine with the idea of increasing its power. These matters, however, we must leave for a future occasion, we have enough on our hands this evening to finish our analysis of the steam engine.

To enable us to bring in a fresh element, we will now briefly recapitulate, and in doing so, we will just take a glance at a table extracted from Box's admirable book on heat, but slightly modified by myself, in so far as the last two items are concerned, for these Mr. Box puts into one, and calls it "63 per cent. utilised in production of steam," whereas I call it 8½ per cent. wasted in heating water and only 54½ per cent. utilised in producing steam.

Units.		Per cent.		Foot-lbs.	
650	—	5	—	501,800	lost in ashes.
2,600	—	20	—	2,007,200	,, by chimney.
1,560	—	12	—	1,204,320	,, by radiation in Boiler-House.
1,101	—	8·5	—	849,972	,, by raising water 62° to 212°.
7,089	—	54·5	—	5,472,708	utilised in expanding to Steam.
13,000	—	100·0	—	10,036,000	

If we were to construct a similar table to the above, but representing an internal combustion, caloric, or gas engine, and allowing similar proportions of loss for ashes and radiation, we should find we had 83 per cent utilised as against only 54½ per cent. with steam.

Accepting the steam table, we find some 5 per cent. of the potential energy lost in the ashes and never developed at all. This, you may see, is indicated in the diagram. Then again there is 20 per cent. which goes straight up the chimney; not that we can say this is all lost, for without the rarefied chimney column we would have no draught. Probably there are some in this room who are able to say whether 20 per cent. is necessary for this light work. If so, it requires nearly double the amount of energy to produce the draught than we can get off the strap from the engine, which is absurd.

We have now got fairly into our boiler, so to speak, and still we find we cannot keep hold of all. About 12 per cent. is lost from the shell of the boiler, leaving, as before stated, only 54½ per cent. to pass through the stop-cock.

This 54½ per cent. might be variously further analysed, according to the kind of engine to be driven. First of all there is a considerable deduction to be made for friction, leakage and condensation between the boiler and the piston. In many cases with

refinements, double the above figures may be realised. But in the very best of engines, with all the latest improvements and elaborations, not more than 12½ per cent. has ever been realised, nor is it possible to realise. The 12½ per cent. can only be got by the finest of wire drawing, and the best of coal; and even then, it does not follow, that when we come to the pounds, shillings, and pence of the matter, the greatest economy of heat units runs parallel with economy in pence. For, we may have to pay more for the fuel to begin with, and more interest on capital sunk in the greater elaborations of machinery, besides a proportional increase of wear and tare, and oil and attention; items not always taken into account by the so-called practical engineer, who very often strains at a gnat in the workshop, and swallows a camel in the stores and counting-house. An engineer requires tact and insight as well as any man. Brute force may wring another half per cent. out of an engine or a human being, but it may be obtained at the sacrifice of twice the value from some other part.

And now, gentlemen, as you will be getting tired of me if I continue much longer, I will cease with the hope that I have presented to you food for thought and raised the temperature of your minds to a warm discussion.

DISCUSSION.

Mr. Samuel Dixon thought it was not, strictly speaking, his province to open the discussion, it being a question more for the boiler-maker than for the engineer, and his position regarding the subject was rather that of the critic. The diagrams exhibited by the author were very instructive, and, indeed, contained even more information than he had explained. He was sure if they considered in the first instance the ends they aimed at when commencing to utilize a pound of coal, and then looked at the results attained, they must be struck with their incompetency, or at any rate inefficiency, and he thought it was certainly incumbent on engineers to try and diminish those immense losses which occurred. If he rightly understood, the author conceived that 12½ per cent. was the highest results which they would be able to get by their present means, but he (Mr. Dixon) certainly was of opinion that they would get a much higher per centage in the future. The diagram pointed out that a tremendous amount of heat went up the chimneys, or what might be termed the monuments of boiler-makers' incompetency, and which were to be seen all over the country. Those immense long chimney shafts were carrying away an enormous amount of energy, and, in his opinion, they were the most extravagant means of obtaining a draught, though of course they had become so accustomed to them that they were regarded almost as a necessity. In order to get rid of those long chimney shafts, the question should be looked upon as a chemical one, and the boiler supplied with the requisite amount of air for burning the fuel, the products being dealt with in the same manner as in the gas works.

Again, there was room for further improvement in the furnaces of our steam boilers, and although there was any amount of steam boilers with all kinds of fantastic tubes, they really saw very little improvement in the furnaces. In that direction, and if treated from a chemical standpoint, he thought they would reduce the waste in energy. There was a certain amount of air

and Liverpool, namely, in a range of boilers to have a chimney to each boiler. The cost of that system however was so great in the original outlay for additional boilers on the slow combustion principle as to be out of all proportion to the economical results that accrued. He only knew of one mill without chimney, and there a draught was created by a blower; this was not a success. If they were to dispense with tall chimney shafts it would either necessitate an enormous amount of boiler power, or forced draught. A jet of steam either in the chimney bottom or over the bars were equally useless. The general use of the mechanical draught, however, was commercially impracticable on account of its enormous cost, while the mechanical stoker had not been a success in that direction. It was found that the present system was the best; they must not forget that the chimney had other functions to perform, such as to carry off the vapours, which in the absence of smoke were often more noxious than the smoke itself.

Concluding, Mr. Boswell pointed out that the Babcock Boiler had been tried in comparison with the Lancashire Boiler, and in no case that had come to his knowledge had it had any effect in depreciating the superiority of the latter, but rather the reverse.

The cold or flameless zone had been spoken of; this might be found in experiments, but it did not in his opinion exist to an appreciable extent under a steam boiler, as they frequently had cases of burning and overheating with water in the boiler.

Mr. John Taylor having expressed his appreciation of the author's paper, said that from it they had to infer that they were only utilizing about one-eighth of the power of the coal. and in reference to that assertion he might tell them that so far back as the year 1855, while attending a course of lectures under a certain Dr. Booth, that gentleman practically came to the same conclusion on this subject as the author, thus evincing that during the interim no progress had been made. Their late member, Mr. Baldwin, likewise went thoroughly into the subject coming to a similar conclusion. He himself, however, did not think it was altogether right to say that they only used one-eighth of their power simply because something else was essential

to get that power. With reference to the chimneys, Mr. Dixon had failed to point out or suggest any improvement in that direction, or anything to replace them. Although they might say that only a stipulated quantity of air was necessary to burn 1lb. of coal, in practice it was found that different kinds of coal required variable quantities, it differing according to the atmosphere or temperature. He quite concurred with the generally accepted opinion that the invisible gases were infinitely more deleterious to health and vegetation than the black smoke. A preventive against either of these disadvantages was, he believed, slow firing and letting the coal get thoroughly ignited, a view in which James Watt was a great believer. Ample provision should be made for the raising and generating of steam, and only just enough space left between the bars as was necessary, since the moment more air was allowed to pass through the bars than was requisite for combustion then they were simply destroying that which they were endeavouring to create.

Regarding the statement of engines only consuming 2lbs. of coal per H.P. per hour, he really could not accept it, but believed that 2¼lbs. was the best result obtained. There were only two lines on which they had endeavoured to progress in this direction, the one to raise the pressure in order to get more expansive steam, and the other to improve the mechanism of the engine. Mr. Taylor concluded with remarking that the present style of boiler was almost universal, and in interestingly alluding to the increase made in the knowledge of engineering mechanism of later years.

Mr. Joseph Nasmith, in moving that the best thanks of the meeting be given to Mr. Guthrie for his valuable contribution to the records of the Association, remarked that Mr. Taylor had put the question on its practical basis. The whole subject had been repeatedly discussed and equally as often left without result. He was inclined to think that it would eventually find a solution by the use of gas, and that in the future they would be able to get out of the gas engine more effect and more foot pounds of work than the steam engine could possibly yield. Of course the gas engine was only in its infancy, and wanted the

boiler furnace and the combustion more incomplete, as analys of the exhaust would show. In further answer, in reference the remarks on the time necessary for good firing, it should borne in mind that there was a point, which if exceeded, more he would be lost by the additional air carrying it to the chimne and in the greater time for loss by radiation, than would be gaine by the more perfect combustion. Heat very quickly radiate notwithstanding the coating and other arrangements which wer used to keep the boiler and flues warm, so that there must b a limit even to the time for good firing.

As regarded the using of the waste gases, the economiser wa very valuable in that direction, since in many cases where the could centralise the generative power the economiser could b utilized, and so increase their 8lbs. of water per lb. of coal t 10, which was a very good result.

Respecting the future of the steam engine, he was inclined t think Mr. Rawlinson had hit the right nail on the head in statin that they had started wrong in boiling the water at all. Th possibilities of the steam engine were practically exhausted, and as several speakers had evidenced, he was not singular in thinking that the gas engine was the engine of the future. Its possibilitie compared with the steam engine were fairly represented by the diagram in comparing the proportion of the width across the furnace against that across the boiler which were as five to one, that was to say, the possibilities of the gas engine were five times greater than the steam engine.

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CONTINUOUS PNEUMATIC RAILWAY BRAKES.

The subject of Railway Brakes is one undoubtedly full of importance, not merely to the engineer, but to the whole civilised community.

Mr. Webb, of the London and North Western Railway, speaking of the grand railway system, in an address to this Association in 1882, said: "There were in the world about "220,000 miles of railway, employing about one million of "people, and carrying annually 1,500 million passengers and "850 million tons of goods." This wonderful system enters so largely into the daily life of the people that any work which has for its object the perfecting of such system should be cultivated and improved with the most zealous care.

It is a matter for congratulation that inventors have during the last twenty years been earnestly devoting their minds to the question of the brake, for in that period no less than 1,140 patents for brakes have passed through the Patent Office, being an average of more than one per week.

Beyond doubt, he who advances but one step towards making the brake perfect, becomes, in a sense, a public benefactor. What nobler work can a man undertake than that which aims at the prevention of loss of human life? And who can tell how much unhappiness might have been avoided in the past if an invention for retarding the motion of railway trains had been perfected and brought into practical use when railways were first introduced? But, as stated to this Association six years ago by Mr. Gresham, a former president, "It was (then) "only within the last ten years that brakes had received that "public attention which their importance demanded. Prior "to this time the burning question of the day was more "particularly concentrated on how best to increase speed, the "question of stoppage being then considered of much minor "importance."

The circumstances of the times, however, have forced the brake question to the front, and it is now known by the title of the "Battle of the Brakes."

Happily, in our day, the continuous brake is regarded as one of the most important parts of a railway rolling stock, and therefore receives a large share of attention.

Generally speaking, the brake is to the railway what the lifeboat is to the ocean—a life-saving apparatus—for in time of danger it must be capable of immediate action. It must not only possess this function, but it must also be useful under ordinary circumstances, as a train-stopper. It must make a good quick and a good easy stop; it must be capable of graduation to a nicety; and it must be able to control trains travelling down an incline.

To give a history of the railway brake, though very interesting, would be impossible in the time at our disposal to-night. I shall, therefore, confine myself principally to a practical description of those brakes which are most generally used, and shall endeavour throughout my paper to handle the subject in a spirit of truth, and to deal with the various points with a view to eliciting facts.

The attention of the Railway Companies was called by the Board of Trade in 1868 to the necessity for providing more brake power; and in the year 1875 the famous Newark brake trials took place on the Midland Railway, under the superintendence of the Board of Trade, when eight brakes were entered into competition, four of which were Pneumatic brakes, viz: Smith's Vacuum, Westinghouse Vacuum, Westinghouse Automatic Pressure, and Steel Mc.Innes Automatic Pressure.

I take the following from another circular issued by the Board of Trade to the Railway Companies in 1877:—"I am directed "by the Board of Trade to request that you will call the atten- "tion of the Directors of your Company to the paper which has "recently been laid before Parliament, containing the corres- "pondence that has taken place between the Board of Trade and "the Railway Association relative to the use of continuous "brakes. In that report will be found the details of the "circumstances attending all the accidents which have been "investgated by the officers of the Board of Trade during the "past year, from a careful examination of which and similar "information for the past few years the Board of Trade are led "to conclude that three-fourths of those accidents might

"probably have been avoided, or the results materially mitigated, "if the passenger trains concerned had been provided *with* "*continuous* brakes."

With regard to the requirements of a continuous brake, it says: "In the opinion of the Board of Trade these conditions should be as follows:—

"(*a*) The brakes to be efficient in stopping trains, instanta- "neous in their action, and capable of being applied without "difficulty by engine drivers or guards.

"(*b*) In case of accident to be instantaneously self-acting.

"(*c*) The brakes to be put on and taken off (with facility) on the engine, and every vehicle of a train.

"(*d*) The brakes to be regularly used in daily working.

"(*e*) The materials employed to be of a durable character, "so as to be easily maintained and kept in order."

A glance at these recommendations will show that they are capable of being fulfilled in their entirety by automatic brakes only, inasmuch as the second condition requires a brake to be self-acting.

A Pneumatic brake is one in which the air we breathe naturally is used through the aid of mechanism for the purpose of preventing railway accidents.

It has been found from experience that the system of utilizing the atmosphere for working a continuous brake is the most convenient, and gives the best results. The connections between the coaches can be made more readily and perfectly than with any other practical system yet invented.

Pneumatic brakes are of two kinds—one being worked by a pressure of air below that of the atmosphere, obtained through the medium of an exhausting pump or steam jet ejector; and the other worked by a pressure of air above that of the atmosphere, the air being compressed by a pump.

Continuous Pneumatic brakes are also of two kinds—Automatic and *Non*-Automatic.

An *Automatic* brake is one in which the power is always kept stored up ready for use when required. As its name indicates, it is *automatic*, or self-applying, in case of a train becoming accidentally divided.

On the other hand, a *Non*-Automatic brake is one in which

the power is *produced when it is needed*, and consequently is not self-acting.

As regards the *Automatic* brake, many illustrations could be given to show the desirability of using this description of brake, but time will not permit. Suffice it to say that, should a train fitted with such an apparatus become detached while travelling, the brakes would be immediately brought into operation, and each portion of the train stopped.

It is easy to conceive how important a matter this would be if the train became detached *while travelling on an incline*, and how disastrous the consequences might be if the train were not fitted with a self-acting brake.

Again, an *Automatic* brake is, as it were, a "*tell-tale*" as regards its own efficiency, for it is self-applying in the event of any damage occurring to any of its parts.

The best method of using a brake for stopping a train is to apply as much force as possible, short of that which will skid or stop the wheels from revolving. This has been proved over and over again from careful experiments. It is no longer a theorem, but a fact. Therefore, the best train-stopper is the brake which admits of the greatest regulation of its power, so as to accord with the varying speeds.

In the method usually adopted in applying an air brake, blocks are hung at both sides of the wheels, and are worked with a cylinder actuated by air pressure. When this pressure is applied to the piston it forces the blocks against the wheels, through the medium of the levers, with a power proportionate to the amount of air pressure acting on the piston. Practically, there are in use in this country three kinds of Pneumatic brakes—viz.:

Vacuum, Non-automatic,
Westinghouse Compressed Air Automatic,
Vacuum Automatic.

I propose to give a description of each of these brakes, but before doing so I will explain the Westinghouse *non-Automatic* brake, which is adopted to a slight extent. I deem this advisable, with a view to making my observations on Pneumatic brakes more complete.

I may here remark that the latest Board of Trade returns show that Vacuum brakes are in use on 4,092 engines and 24,035 carriages, and compressed air brakes on 1,760 engines and 14,869 carriages.

I will proceed with the

WESTINGHOUSE NON-AUTOMATIC COMPRESSED AIR BRAKE.

This brake is worked by means of compressed air, but, as its name implies, is not self-acting. Moreover, the engine driver is the only person who can use it.

A pump on the engine compresses air into a large reservoir under the footplate, in which reservoir is carried a considerable quantity of atmosphere under compression, to say, 60 or 80 lb. per square inch.

A pipe extends along the train, and is connected from coach to coach by means of flexible rubber hose pipes, fitted with suitable couplings.

A cylinder for actuating the levers, which pull the blocks to the wheels, is placed under the engine and tender, and under each carriage, a connection being taken from every cylinder to the continuous, or as it is generally called, the "train pipe."

By allowing compressed air to flow into the cylinders the pistons are forced out and the brakes applied. The reservoir under the foot plate has a pipe attached to it through which the air is conveyed to a valve used by the driver for putting on and taking off the brake. This valve has another pipe carried from it to the train pipe. When the driver desires to apply the brake he moves his valve, and this brings the compressed air in the reservoir into communication with the train pipe. To release the brake the driver's valve is turned back to its former position, allowing the air to flow out, and thus taking the pressure off the pistons.

Having explained the *non-automatic* form of the compressed air brake, I will direct your attention to the non-automatic form of the *vacuum* brake.

VACUUM NON-AUTOMATIC BRAKE.

This brake is worked by the pressure of the atmosphere brought into action by means of exhaustion.

A steam jet ejector on the engine, supplied with steam from

the boiler, has a pipe attached to it which is carried along the train, and is known as the continuous or train pipe. It is connected between the vehicles by rubber hose with couplings.

Under each vehicle is fixed a cylinder having a connection with the train pipe. The piston rods of these cylinders are attached to the brake gear for applying the blocks to the wheels, so that any movement of the piston will give a corresponding motion to the brake blocks.

To apply the brake the driver admits steam to the ejector by moving a handle; the steam passing through the ejector cones at a great velocity, carries the air with it, and by this means exhausts all the cylinders along the train.

By moving the handle in the opposite direction, air is allowed to enter the train pipe and destroy the vacuum in the cylinders, thus releasing the brake. The power of the brake is controlled by the amount of vacuum created.

The cylinder is of peculiar construction, and is made in halves, bolted together at the centre, the flanges holding between them a blocked piece of rubber or leather, to which are attached two iron plates with the piston rod. The advantage of this kind of cylinder and diaphragm, or flexible piston, is that the movement is obtained without friction.

The great drawback of all *non-automatic* brakes has been that a hose coupling might become detached, or some damage to the brake take place, which would prevent the power being applied when needed. When such an accident did occur, the driver would know nothing of it until he required his brake.

To overcome this difficulty in the *vacuum* brake, Mr. Gresham invented a simple and ingenious device, which is known as the "tell-tale." It consists of a very small ejector, placed on the engine and supplied with steam sufficient only to create throughout the train pipe and cylinders a slight vacuum, but not enough to cause the brakes to be applied. This vacuum is indicated on the engine and in the vans by a gauge, exhibiting on a tablet the word "Right" on a white ground. Now suppose a hose coupling to come undone, or the pipes or cylinders to be damaged. The small vacuum would be

destroyed; the white tablet would immediately disappear, and a red one take its place with the word "Wrong" upon it, showing that something had happened to the brake, and that it could not be depended upon to stop the train until it was rectified.

When desired the gauge has a gong attached to it which is so constructed that it rings whenever the red tablet appears, audibly calling attention to the brakes being out of order.

We now come to the more important form of brakes—viz., those constructed on the Automatic principle, which are becoming universally adopted.

I will take first the one worked by compressed air, and called

THE WESTINGHOUSE COMPRESSSED AIR AUTOMATIC BRAKE.

This brake fulfils all the requirements of the Board of Trade Circular. It can be applied by the driver and by the guard; it is self-applying in the event of an accidental severance of the train, or of damage to the train pipe; and, if desired, it can be arranged so that the passengers themselves can apply it.

A donkey pump is fixed on the engine for the purpose of compressing the air necessary for the working of the brake. The air is forced into a large reservoir placed under the foot-plate. It then passes from this reservoir through the driver's application valve, and along the train pipe, from which pipe a supply of compressed air is conveyed to a reservoir on every vehicle of the train. Each coach, therefore carries its own power for working the brake.

There is placed under the engine and tender, and under each carriage, besides the reservoir, a brake cylinder for applying the blocks to the wheels, and an application valve commonly called the "triple valve" for the purpose of controlling the passage of compressed air in the reservoir to and from the cylinder.

The apparatus is so arranged that, whilst the brakes are off, the train pipe is kept charged with compressed air, as are also the reservoirs; but if the pressure in the train pipe is released, either by design or accident, the application valves open, and the air in the reservoirs is allowed to flow into the cylinders, thus applying the brake. By again charging the train pipe, the

application valves are returned to their former position, and the air let into the cylinder is released into the atmosphere.

Having given you a *general* description of this brake, I propose now to request your attention to its details, whilst I endeavour to explain the working of each part, in order that the ways and means which are employed to obtain the ends necessary in a continuous automatic brake may be thoroughly understood. I would ask you to bear in mind that each carriage is fitted with a complete brake apparatus, which consists of the following parts:—

1st. Train pipe with hose couplings.
2nd. Two train pipe cocks.
3rd. Reservoir.
4th. Application valve.
5th. Double piston cylinder.
6th. Release valve.

The train pipe is used for the purpose of conveying compressed air along the train.

The hose and couplings are fixed at the ends of the vehicle, and are used for connecting the pipe of one coach to that of another. I have here a model of these hose and couplings, so that the method of coupling and uncoupling may be inspected.

One of the train pipe cocks is placed at each end of the vehicle. These cocks are used in order to close the pipe at the rear of the train. They must also be shut before uncoupling one coach from another in order that the act of disconnecting may not release the air and apply the brake. The cocks are of ordinary construction and require no description.

The reservoir is a wrought iron cylindrical vessel.

The application valve is generally known as the "triple valve." It is the most important portion of the brake which depends entirely upon its action. Drawing No. 1 shows a section of this valve to which I will ask your attention. The valve is ingenious, but complicated.

It consists principally of three valves, viz.: A piston valve (1); a circular-faced slide valve (2); and a conical seated valve (3. It has also three branches. The one marked 4 is connected to the train pipe; 5 to the reservoir; and

6 to the cylinder. Compressed air flows from the train pipe through the branch 4 and descends to the space below the piston 1 forcing and holding it up in the position indicated. The air then passes the piston through a small groove, (10), known as the "feeding groove," thence flowing to the branch 5 and into the reservoir.

No air can as yet get into the brake cylinder, as its port is covered by the slide valve (2). A groove (7) in the face of this valve keeps the cylinder in communication with the atmosphere through the hole (8) drilled in the valve body.

Assume for a moment that an application of the brake is desired. For this purpose the pressure in the train pipe must be released, when the air below the piston (1) will be allowed to escape, and the pressure will be removed. The piston is then forced down by the pressure in the reservoir. It first passes over the feeding groove (10), and moves the slide valve (2), closing the port (6) from the atmosphere and opening it to the reservoir, when the air in the reservoir flows into the brake cylinder, presses out the pistons, and applies the brake.

By again admitting compressed air to the train pipe it forces up the piston (1) and slide valve (2) into the position as drawn. The air passes the feeding groove and replenishes the reservoir, and the air in the brake cylinder releases itself by flowing into the atmosphere through the hole (8).

We have now, as it were, made an application of the brake, and released it.

A brake to be perfect, however, must be capable of graduation, and it is with this view that the conical seated valve (3) is introduced, it being found impossible to adjust by means of the slide valve (2).

To make a slight application of the brake, the pressure in the train pipe and below the piston 1 is reduced slowly; the piston descends (but not so quickly as in the case of a full application) and opens the valve 3 before moving the slide valve 2. When the latter valve has travelled far enough, 1st, to close the release port 8, and 2nd, to open the valve 3 to the passage 6, the air flows from the

reservoir and into the brake cylinder until the pressure above the piston 1 becomes less than that below. The piston is then again forced up, not with sufficient power to overcome the friction of and move the slide valve 2 but simply to close the conical valve 3. By again very slowly diminishing the pressure in the train pipe the same action takes place, and the pressure in the brake cylinder is increased.

The pressure in the brake cylinder cannot, however, be reduced, except by moving the slide valve. Consequently, as this slide valve is incapable of regulating the brake in increasing the pressure, neither can it be utilised in decreasing the pressure.

In this valve therefore there is absent that very important feature which would enable the brake to be reduced in pressure to prevent skidding.

The brake cylinder is shown on Drawing No. 2. It is fitted with two pistons (1), both of which are packed to keep them air-tight with a cupped leather (2), which is held against the inside of the cylinder by a coil of steel wire (3). The covers (4) are made hollow, with bearings in the centre, through which pass the piston rods (5), these covers receiving inside them strong spiral springs (6) placed around the piston rods for releasing the brakes when the compressed air leaves the cylinder.

This cylinder is placed in the centre of the coach in a horizontal position, one piston actuating the levers which apply the blocks to one pair of wheels, the other piston working the levers for the second pair of wheels.

The connection (7) for receiving the compressed air is placed in the centre of the cylinder, and when the air is admitted drives the pistons in opposite directions, so pushing the levers actuating the blocks.

Considerable trouble was experienced with this brake when first introduced, owing to the fact that any reduction of pressure in the train pipe, however slight, moved the application valve, and applied the brake.

To overcome this difficulty leakage grooves were added. The groove (8) cut in the cylinder past one of the pistons is made for the purpose of allowing any very slow admission of air between

the pistons to pass away without applying the brakes. The feeding groove in the application valve acts in a similar way: but supposing the piston of this valve to move over such groove the small hole (9) drilled in the slide valve face comes into use, and acts in the following manner :—

During the movement of the slide valve downwards, the hole is brought opposite the cylinder port before the release hole (8) is closed, and the pressure is thus allowed to escape without applying the brake.

The release valve is used for the purpose of releasing the brake by hand when a coach is detached from an engine. It is shown on drawing No. 3.

The valve used by the driver for working the brake is called the "driver's brake valve," its object being to control the pressure in the train pipe, by which means the application or "triple" valves under each vehicle are manipulated.

It consists of a conical seated valve, the function of which is to let the air flow out of the train pipe ; a disc valve for allowing air to pass from the main reservoir to the train pipe ; and a feeding valve for replenishing any leakage of air.

The valve has three positions :—

1st. *The feeding or release position*, in which the air from the main reservoir passes through the disc valve, to the train pipe, and acts upon the brake through the medium of the application valves, as already described.

2nd. *The running position.* In this the disc valve is closed, but air can still flow to the train pipe by passing the feeding valve. The object of this is to prevent the brake being applied through leakage in the pipe, and also to maintain a constant pressure throughout the train. This valve is loaded with a spring, to allow the main reservoir always to have an excess pressure of 10lbs. over that used along the train, to assist in recharging the train after using the brake.

3rd. *The brake on position*, when the pressure in the train pipe is allowed to flow into the atmosphere, thereby applying the brake.

I have now to describe

THE VACUUM AUTOMATIC BRAKE,

which will, no doubt, be readily followed by those who have inspected the working of the brake, on a full-sized model, at the works of Messrs. Gresham and Craven, of this city.

This brake fulfils all the requirements of the Board of Trade. It can be applied by the driver, by the guards, and by the passengers, if desired. It is self-applying when a train is broken into two or more portions by accident; and it is self-applying also in case of the train pipe or the brake apparatus itself becoming damaged.

Under each vehicle is placed a brake cylinder, with valve complete in one fixing, having a connection by a small hose pipe to the continuous train pipe running from end to end of the train, and coupled between the coaches by means of hose pipes and couplings. On the engine is fixed an ejector, called the "Combination Ejector," for the purpose of creating and maintaining the vacuum, the driver's valve being also upon it.

To prepare the brake for use, or, as it is generally termed, to "create the vacuum," the driver sets the ejector to work by admitting the required amount of steam. The pipe and all the cylinders are exhausted, and a vacuum of 20in. to 24in. is created in the apparatus throughout the train.

When it is desired to apply the brake, the driver turns his handle to the position "on," opening the air valve and admitting the atmosphere to the train pipe and bottoms of the pistons, which it lifts up, as there is still a vacuum above them, and pulls the blocks to the wheels.

To *release*, the valve is placed at "slow release" or "running" position. The ejector then withdraws the air let in to apply the brakes, thus restoring the equilibrium of the pistons and allowing them to fall and carry the blocks from the wheels.

This is practically what I may term a *general* description. With your permission I will enter into the details.

Each coach is fitted with

1st. A train pipe with hose and couplings.
2nd. A cylinder with valve complete.

The train pipe is used for conveying the atmosphere to and from the cylinders. It is connected between the vehicles by hose and couplings; a full-sized model of which is here for inspection.

It will be noticed on the model that each vertical pipe has a cast-iron plug strapped to it. The object of this is to close the pipe at the end of the train, which is done by putting the coupling upon it.

I have now simply to describe the cylinder with its ball valve, as in this lies the element of automaticity, and I shall then have brought under your notice the whole of the fittings required for each coach, which consist practically of a pipe and a cylinder.

The cylinder, Drawing No. 4, is open ended, and is placed inside a wrought-iron vacuum chamber (2). This chamber has two trunnions (3) on its side, which are placed in carriers, the cylinder oscillating to allow of the radial movement of the lever to which it is coupled.

The piston (4) is made a very free fit in the cylinder, and is packed with a rolling ring of India rubber (5), which, as the piston moves, is rolled in compression between it and the cylinder, making a perfectly air-tight packing and without friction. A frictionless metallic piston is thus obtained.

The piston rod (6) is lined with brass, and works in a brass bush. It is also packed with a ring of India rubber (7) to keep it air-tight.

The ball valve is placed at the bottom of the cylinder.

This valve has a branch (1), to which is attached one end of a piece of hose pipe ¼in. internal diameter, the other end being coupled to a connection on the train pipe. The only moving piece in this valve during the using of the brake is the small brass ball (2). The following is what occurs in the working of the brake:—

A vacuum having been created in the train pipe and the air drawn out of the cylinder through the connecting pipe (1), the piston (4) remains at the bottom of the cylinder, as it is still in equilibrium, there being a vacuum at both top and bottom. The air from the top in being withdrawn passes through the valve seating (3), and forces the ball up the incline, thus obtaining a clear passage to the train pipe. When the vacuum

is created the ball rolls down to its seating, and by this means prevents any air from again entering to the top of the piston.

Let us assume that an application of the brake is required.

The driver opens his application valve, and allows air to enter the train pipe and flow to the bottom of the pistons, thus lifting them. The pressure of the brake is regulated by the amount of air let into or withdrawn from the cylinder. A full application is made by allowing sufficient air to enter as will completely fill the space below the pistons. A great advantage in this arrangement is that the graduation can be made successfully, both in the increasing and the decreasing of the brake block pressure.

As before pointed out, a *perfect* brake must permit of its power being gradually reduced, inasmuch, as to prevent skidding of the wheels a less pressure on the brake is required while the speed of the train is being diminished. By this means a *better stop* is made.

When a train or a coach is detached from an engine, the brake can be released by pulling a cord placed at either side of the vehicles. This cord is attached to the release lever (4) of the ball valve, and moves the cage (5) which contains the ball, dragging the ball off its seat and allowing air to rush in on the top side of the piston and destroy the vacuum.

This arrangement is a most excellent one, as it permits of a train being released in a very short time, in fact, as quickly as a porter can walk from one end of the train to the other.

It will be noticed that the spindle is packed with a small leather diaphragm, the purpose of which is to return it to its "ordinary" position, when a vacuum is again created.

As the valve is self-closing (but not before the vacuum is again produced) the cord only requires to be pulled, and need not be held until the release has taken place.

In the guard's van there is a vacuum guage which always indicates the state of the brake; also a valve for applying the brake. This valve opens automatically when the driver makes a sudden application, thus allowing air to enter the train pipe on the van and increase the rapidity of application.

I have now explained the whole of the apparatus except the ejector, which is fixed upon the engine for the purpose of creating the vacuum and working the brake. I have advisedly left this until the last, as I thought it would be more interesting and more readily understood after the description of the brake itself.

As previously stated, this instrument is called the "*Combination Ejector*," and is so styled in consequence of its being a combination of two ejectors and the driver's application valve. A sectional model of this instrument is on the table.

The smaller ejector is placed inside the larger one, and is used for creating the vacuum and maintaining it, to prevent the application of the brake by leakage. The larger ejector is for obtaining the vacuum quickly when desired, and may be considered an auxiliary, as in ordinary working it is very seldom used, the perfection of a stop being made by a slow release of the brake.

The application handle is part of the air disc valve, on the side of the ejector, and is used for letting air into the train pipe. It is fitted on to a spindle as a centre, at the other end of which is attached a steam disc valve for supplying steam to the auxiliary ejector. Thus the driver's handle manipulates the air valve for applying the brake, and the steam valve for working the auxiliary ejector in releasing the brake.

The handle has three positions. When at the top it is in the "*quick release position*," the steam being open to the auxiliary ejector and the air valve closed; midway it is in the "*running position*," both the air valve and the steam valve for the large ejector being closed; at the bottom it is in "*full on position*," the air valve being full open, whilst the steam valve is closed.

The ejector is the most economical method of producing a vacuum, for it must be remembered there is no machinery to keep in motion, and consequently no friction to overcome.

The steam passes through the instrument in an annular jet, coming in contact with the air on its inner surface, which is then carried out along with it. An annular jet of steam is used

in preference to a central one, on account of the greater surface which meets the air, resulting in a more rapid exhaustion.

You will doubtless be desirous of hearing something beyond a description of pneumatic brakes, and, indeed, my paper would not be at all complete were I not to lay before you some observations on the action of the brakes in daily working, other than those already mentioned. I shall confine these observations to *automatic* brakes. I would however, state in a general way that a *non-automatic* form of brake gives very good results in practice; but besides being minus the great advantage of automaticity, it is not as quick in action, and therefore cannot bring a train to rest in so short a distance as can be accomplished by an automatic brake.

The question as to the distance in which the brakes will stop a train is one of the utmost importance. It is also one very difficult to answer precisely. A stop is influenced by the weight of the train: by the portion of that weight resting upon the wheels which have brake blocks applied to them: by the condition of the rails: and by many other circumstances over which the brake can have no control.

I have a copy of some experiments made with two trains similar in every respect, each consisting of engine, tender, and twelve six-wheeled coaches, with brake blocks on four wheels of each. One train was fitted with the compressed air automatic brake; the other with the vacuum automatic brake. The experiments were made with both trains on the same day, and over the same road.

When running at a speed of 50 miles per hour the train fitted with the **compressed air** brake was brought to rest in 20 seconds, and in a distance of 280 yards: that fitted with the **vacuum** brake was stopped in 18 seconds, and in a distance of 253 yards. Had the trains consisted of four-wheeled carriages with brake blocks on all the wheels they would have been stopped in about 200 yards.

natter for consideration also is the time taken to apply the
Two brakes may be capable of exerting equal pressure
ks, and yet not be able to bring a train to rest in the

same distance, even though all the influences with which they have to contend may be identical.

When a train is travelling at a speed of 60 miles per hour it covers a distance of nearly 30 yards per second, and every second lost in the time taken to bring the brakes into action means a certain distance run, without any retarding power being applied. Suppose it takes four seconds to apply a brake to the wheels of a train travelling at the speed named. The train would pass over nearly 120 yards before being brought under the influence of the brake.

Captain Galton tried some very elaborate experiments by means of a recording van placed in a train fitted with the Compressed Air Automatic Brake, and the diagrams taken showed that the brake was applied, on an average, in 2½ seconds.

A similar experiment with a train fitted with the Vacuum Automatic Brake (on one of the principal railways) showed that brake to have been applied in 2 seconds. I have a copy of the diagram with me.

In considering this point, I would ask you to remember that both brakes are applied by the admission of air into a brake cylinder, and that the question is simply one of the time taken after the opening of the application valve or valves for that air to enter the cylinder.

In the first place, the Vacuum Automatic Brake is one worked, as it were, from one immense reservoir, which is the natural atmosphere itself. A movement of one valve is, therefore, sufficient to place every cylinder in a train of any length, in direct communication with this reservoir. The air is thus allowed immediately to flow into all the cylinders. Experiments have shown that the atmosphere rushes along the train pipe at the rate of about 662 feet per second, or 7½ miles per minute.

Again, as regards the Compressed Air Brake, as explained in the description, this brake is not direct-acting, for an application valve is placed under each vehicle of a train. Moreover, it is necessary to destroy about 30 per cent of the pressure in the train pipe *before* these valves are full open, and then there is a greater weight and quantity of air to flow into the cylinder than

with the Vacuum Brake. This will be shown by the following calculations, in which the brake cylinders are taken of the standard diameter, with four inches of stroke, and the ordinary pressure used in each case :—

Cylinder for Compressed Air Brake.

8in. diameter × 4in. stroke + 1in. for waste space between the pistons = 251 cubic inches of air at 60lbs. effective pressure, requiring 1,004 cubic inches of air at atmospheric pressure.

Cylinder for Vacuum Brake.

18in. diameter × 4in. stroke = 1,017 cubic inches of air at 10lbs. effective pressure, requiring only 678 cubic inches of air at atmospheric pressure.

From this it will be seen that nearly 50 per cent. more weight of air must flow into a Westinghouse than into a Vacuum cylinder, and though this air is reduced in bulk by being compressed, yet its weight remains the same, and the passages through which it flows are also considerably less than in the vacuum brake, thus greatly increasing the friction.

Another question of importance is the graduation of the brakes. They must—if they are to meet the requirements of daily working—be capable of being applied with varying degrees of pressure, according to the speed at which the train is travelling. It is also very desirable to so use the brake as to prevent skidding of the wheels, and by this means to make a good and an easy stop. This would avoid wearing flats upon the wheels which, as everybody knows, are so objectionable to passengers, and so expensive to Railway Companies in having to re-turn such flatted wheels.

As an example, let us suppose it is desired to stop a train running at 50 miles per hour. To do this efficiently the brake must be applied with power enough to all but cause the wheels to skid. The speed will then soon be reduced to say 40 miles per hour. Now at this speed a less pressure must be exerted by a brake, or skidding will result, and so on, as the train

gradually comes to rest. The power on the brake blocks therefore must slowly and steadily be diminished.

With the compressed air brake, as I endeavoured to point out in describing the action of the triple valve, no such reduction of pressure can be effected. The nearest approach it can make to this desirable feature is by releasing the brake and re-applying it. With the vacuum however, the pressure may be gradually decreased, and so not only is skidding of the wheels avoided, but the stop is improved. This feature is very much appreciated by those who have to use the brake.

This point leads to another—that of the controlling of trains travelling down inclines.

Consider for a moment what is required from a brake under such circumstances. The object of course is to keep the train under control, not to stop it.

Should the incline be long and severe, the brake ought never to be released whilst running over it. Yet the circumstances will sometimes require a little more and sometimes a little less brake pressure, and it is impossible to meet this demand unless the pressure can be gradually diminished as well as increased.

I would here say a word or two as to the effect of repeated applications when made in rapid succession. I contend that a brake should always have its full power at command when required, whatever calls may have previously been made upon it.

The Vacuum Automatic brake is applied by the admission of air to the cylinder, and it is impossible to release the brake again until all this air is exhausted from the apparatus. The ball valve fixed on the cylinder acts as a back stop-valve, and prevents any admission of air to the top of the piston. The reserve power of the brake, therefore, cannot be interfered with, and so any number of successive applications can be made, the full power of the brake remaining intact.

As in the Vacuum, the Westinghouse brake is applied by the admission of air to the cylinder. This air however, before the brake can be released, must flow into the atmosphere, and this much more quickly than it is possible to replenish the store in the reservoir. The repeated applications thus become each time weaker and weaker, a not very large number of which will entirely use up the reserve of compressed air, and should the

brake at such a time be required in an emergency, it would have no power left with which to act.

The construction of the Westinghouse is such that a more rapid release can be made with it than with the Vacuum. The latter brake, however, begins to release immediately and it can be completely taken off after an application of its full power on an express train in about eight seconds.

The carrying of high pressures is a difficulty, owing to the connections between the coaches (which must be made with rubber or other flexible material) not being capable of withstanding them. The wear and tear of the apparatus become very considerable, to say nothing of the inconvenience and danger of the train being stopped if a hose pipe should burst. On the other hand, in a Vacuum Brake the pressures are all external, and no such difficulty can consequently arise.

The apparatus required for a pressure brake is smaller than what is necessary for one constructed on the Vacuum principle.

With regard to train pipe cocks, a question might be asked, Could they not be used in the Vacuum as well as in the Westinghouse? My answer to this is that they could be applied, there being nothing in the Vacuum brake which prevents their use. They are, however, a necessity in the pressure brake, as without them great delays would take place when detaching coaches on the road.

Experiments have shown that with the Compressed Air Brake, to take a coach off a train of 12 or 13 carriages, without first closing the cocks, would occupy from 3½ to 4 minutes in again securing the full working pressure, whereas with the Vacuum Brake this can be obtained under similar circumstances in about 15 seconds.

The use of cocks has given rise to great difficulties, owing to their being closed either by design or accident, or by carelessness on the part of porters. If they are closed the brake, of necessity, cannot be a continuous one, and the cocks when so closed give no indication either to driver or guard.

With respect to the question of economy. I have studied it thoroughly and carefully, and have compiled tables giving the amount of air

1st. which must be compressed into the brake apparatus of a train of 10 coaches, with engine and tender, when fitted with a Westinghouse brake, and

2nd. the quantity which requires to be exhausted out of the apparatus of a similar train when fitted with a Vacuum Automatic brake.

The following are the tables referred to :—

Table shewing the quantity of air necessary to be compressed into the brake apparatus of a train consisting of engine, tender, and 10 carriages, with 400 feet of piping and connections, when fitted with a **Westinghouse** Automatic Brake.

ARTICLE.	SIZES, &c.	Atmospheric air in cubic inches.
Main reservoir.	2 feet dia. × 2·5 feet long, 13,571 cubic ins. of air at 85lbs. pressure.	= 76,902
Two reservoirs for Engine and Tender.	11½ins. dia. × 22 ins. long, 4,570 cubic ins. of air at 75 lbs. pressure.	= 22,850
Ten reservoirs for carriages.	9½ins. dia. × 20ins. long, 14,176 cubic in. of air at 75 lbs pressure.	= 70,880
400 feet of piping and connections.	3,952 cubic ins. of air at 75 lbs. pressure.	= 19,760
	TOTAL ..	**190,392**

Table shewing the quantity of air required to be exhausted out of the brake apparatus of a train consisting of engine, tender, and 10 carriages, with 400 feet of piping and connections, when fitted with a **Vacuum** Automatic Brake.

ARTICLE.	SIZES, &c.	Atmospheric air in cubic inches.
Vacuum Chamber for Engine and Tender.	17½ins. dia. × 44ins. long, 10,582 cubic ins. of air at 21ins. of mercury.	= 7,408
Two cylinders for Engine and Tender.	21in. dia. × 12in. long, 8,312 cubic ins. of air at 21ins. of mercury.	= 5,818
Ten carriage cylinders.	18ins. dia.—contents, 54,259 cubic ins. of air at 21ins. of mercury.	= 37,981
400 feet of piping and connections.	15,150 cubic ins. of air at 21ins. of mercury.	= 10,605
	TOTAL ..	**61,812**

It will be seen from these tables that the Westinghouse brake requires more than three times the quantity of air to be dealt with than is necessary with the Vacuum brake, and *economy of air* will of course mean economy of steam in dealing with it.

It might be desired to know the amount of this air which is used in applying the brakes fully.

The instructions for working the Westinghouse brake state that only 25lbs. per square inch need be allowed to escape from the train pipe for this purpose, and as we have assumed a working pressure of 75lbs. it is equivalent to releasing one-third of the quantity or weight of air in this pipe.

The following tables give the amount used in each brake : —

Air used in making a full application of the **Westinghouse** Automatic Brake.

ARTICLE.	SIZES, &c.	Atmospheric air in cubic inches.
Two engine cylinders.	6ins. dia. × 4ins. stroke + ¼in. waste space = 254 cubic ins. of air at 60lbs.	= 1,017
Tender cylinder.	13ins. dia. × 4in. stroke + ¼in. waste space = 597 cubic ins. of air at 60lbs.	= 2,388
Ten carriage cylinders.	8ins. dia. × 4ins. stroke + 1in. waste space = 2,510 cub. ins. of air at 60lbs.	= 10,040
400 feet of piping and connections.	3,952 cubic ins. of air at 75lbs. pres. (one-third only of this)	= 6,586
	TOTAL ..	**20,031**

Air used in making a full application of the **Vacuum** Automatic Brake.

ARTICLE.	SIZES, &c.	Atmospheric air in cubic inches.
Two Engine and Tender cylinders.	21ins. dia. × 4ins. stroke, 2,770 cubic ins. of air at 21ins. of mercury	= 1,939
Ten carriage cylinders.	18ins. dia. × 4ins. stroke, 10,170 cubic ins. of air at 21ins. of mercury	= 7,119
400 feet of piping and connections.	15,150 cubic. ins. of air at 21ins. of mercury	= 10,605
	TOTAL ..	**19,663**

These tables shew that the amount of air used in making a full application is about the same in each case, but slightly in favour of the Vacuum.

Another consideration to which I ought to call your attention is that of the *cost of maintenance.*

This cost as regards the Westinghouse brake has been very completely indicated in a report by Mr. Harrison of the North Eastern Railway, on which railway this brake is largely used.

The amount for examination and cleaning is stated to be 7s. 2d. per coach per annum. Considerably more than one-half of this sum is put down for the renewal of hose pipes burst through the use of high pressure.

As far as the Vacuum brake is concerned, external pressure only being used, hose pipes cannot burst, and therefore no expense is incurred on this head.

With respect to the remainder of the 7s. 2d., this is caused in a very large measure by the frequent periodical examinations which are required in the Westinghouse brake, such as the cleaning of "triple valves," the cleaning and lubrication of cylinders, &c.

Now these examinations are conspicuous by their absence in connection with the Vacuum brake. There being no friction either in the ball valve or the cylinder, such examinations and lubrication are unnecessary.

The cost of brake blocks is about the same in each case. It is given in the report already referred to as 6s. 6½d. per coach per annum.

Both Automatic brakes can be used for slipping coaches. In the Westinghouse the cocks in the train pipe can be closed for this purpose. In the Vacuum, cocks are placed between the ordinary couplings.

A great deal might be said as to the original inventors of Automatic brakes, and much interesting information on the brake question might be given, but I have already occupied your time long enough. I will, therefore, conclude by thanking you for the kind attention you have given me, and by saying that should anyone present desire further information respecting the brakes, I shall be very pleased to give it.

The apparatus on the table may be inspected, if desired, after the meeting.

DISCUSSION.

The President, in opening the discussion, said that probably there was only one feeling amongst the audience that evening—namely, of thankfulness to the essayist, and of appreciation for the graphic description they had had of the various brakes. And also they would probably favourably remember Messrs. Gresham and Craven for their kindness in not only preparing the models placed before them that evening, but also in assisting in the preparation of the diagrams, as well as permission to inspect the models at their works. He could not concur with all that the essayist had said, though as regarded the two systems certainly the Vacuum Automatic brake was the simplest, and consequently it must cost a great deal less for maintenance than the other automatic brake described. Ingenuity could not be directed to a more useful quarter than when it was devoted to regulating and controlling and placing under absolute subjection the great forces of steam, especially in connection with locomotion or marine engineering, for the prevention of accidents and the saving of life. Generally all great works of utility had their martyrs, as well as every moral force which had benefited mankind. Consequent on the speed of their railways and steamships there were many terrible accidents, and so it was a great public benefit to mankind when intellectual men devoted their energies to the perfection of such beautiful inventions as had been described that evening.

Mr. T. Daniels, after remarking that steam brakes seemed to be falling into disuse, briefly alluded to several ingenious devices in the Vacuum Automatic brake, which he characterised as worthy of every success.

Mr. Goulty drew attention to the jerking sensation experienced in the application of the brakes, and said they would l short of perfection until that was remedied.

Mr. G. Lewis remarked that the manner in which Mr. Gresham had overcome the difficulties of friction in his automatic system was very ingenious indeed, which was no small achievement in a system which was left so much to itself.

Mr. Gresham said it was scarcely correct to say that steam brakes were falling into disuse, because they had never been in use as a continuous brake, owing to the steam becoming condensed long before it could get to the end of the train. They were, however, used on the engines of the Midland, the London and North Western and other railways, being made to work in connection with the continuous Vacuum brake.

As regarded the distance taken in stopping trains, he would like it to be understood that there was a limit to the distance in which this could be done; fifty miles an hour was the average speed of an express train, and if such a train was pulled up within 200 yards it would be very satisfactory.

With reference to the jerking sensation alluded to, this would not take place, if the blocks were evenly adjusted, the coaches properly tightened up, and the brakes gradually released as the train came to rest. The coaches being loosely coupled together and the blocks not being evenly adjusted, one coach would be braked before another, causing the buffer springs to become compressed, and when the brakes were released, the return of these springs caused the jerking referred to.

As regarding the automatic vacuum brake, he said they did not claim any credit for having invented any new principle about it. As a matter of fact, the power of using pressures below the atmosphere had been thoroughly described in the Patent Office Records twenty-five years ago, and it was about that period since he (Mr. Gresham) took out his first patent for brakes, worked by the atmosphere, both for pressures below and above.

Mr. Gresham then briefly referred to the origin of the various brakes, shewing that they were indubitably English, and not American inventions, and concluded with generously acknowledging the able assistance which he himself had received from the essayist and other assistants in working out the details of the automatic vacuum brake.

Mr. Thomas Ashbury, in proposing the customary vote of thanks to the essayist, said he remembered some ten years ago reading a paper before the Association on "Railway Brakes," when he sketched out something like thirty brakes of different kinds which, up to that time, had been in use on the railway system, finishing up with the Smith Vacuum Brake, which had only just made its appearance. Mr. Smith was a Carlisle man, and he (Mr. Ashbury) had the pleasure of being associated with him in many of his experiments on the Metropolitan line and other systems, in fact making for Mr. Smith some of his experimental brake gear and ejectors. At that time he was firmly of opinion that that brake had a great future before it, though it was only then in its infancy. In its simplicity, however, there were the elements of success, and some of the results obtained at that time in stopping trains have scarcely been excelled. He begged to move that a vote of thanks be presented to Mr. Kiernan for his very able essay that evening, and also to Mr. Gresham, and through him to the firm, for the generous manner in which they had seconded Mr. Kiernan's endeavours to make his paper, as far as possible, perfect, both in the preparation of the diagrams and in allowing the members to visit their works and see the apparatus in operation.

Mr. E. Asquith seconded the motion, and it was carried with acclamation.

Mr. Kiernan briefly returned thanks, and the proceedings terminated.

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THE CONSERVATION OF ENERGY.

A PAPER

READ BY

MR. SAMUEL DIXON, M.I.M.E.,

(Member of the Association,)

ON 12TH MARCH, 1887,

AT THE GRAND HOTEL, MANCHESTER,

Alderman W. H. BAILEY, J.P., President,

IN THE CHAIR.

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THE CONSERVATION OF ENERGY.

Exactly twelve months since this evening I had the honour of reading a paper before our Association here on the Conservation of Energy, and as a desire was expressed that I should carry the subject a stage further in another paper, it is now my object to endeavour to do so.

As I have entered at considerable length in the previous paper into the reasons by which this fundamental law has been established, I will not again go over the ground upon which the proof of the great principle of conservation of energy rests, but simply state this principle, and in a general review of the several branches of engineering endeavour to shew that it holds true universally. The principle of the conservation of energy asserts that we cannot *create* energy neither can we *destroy* it. This is a very brief statement, but without considerable reflection we cannot realize fully the extent of its meaning, for since its establishment it has been made the touchstone or test of innumerable theories, any one of which being found inconsistent with its law has been compelled to yield. The importance of this principle is exceedingly great, more particularly to us as engineers who are daily in contact with some one or other of the various forms of energy, and it is important that we at the outset should realise our true position, being concerned as we are, not in the *creation* of energy, but simply in its *transformation* and *transmission* from one place to another.

Now, whilst I would emphasise the fact that we cannot *destroy* energy, I would not desire to convey the impression that we cannot *waste* or *dissipate* it; on the contrary, it is this particular point which I wish to bring forward so that we may see fully our position in the economy of the world.

What is a well-known fact, and what I endeavoured to emphasise in my previous paper, is that the only important source of energy available to us is our coal, which nature has so abundantly provided, but which is nevertheless of limited amount. I would endeavour this evening to trace this enormous stream of energy from its source in our coalfields to its final dissipation at the hands mainly of engineers. I would, as it were, walk along the banks of this enormous stream and note the use which is being made of it by engineers particularly, and endeavour to estimate honestly the relative efficiencies of the various mechanical and other appliances dealing with it. My object is to endeavour to rouse our minds from that self-satisfied state which is so dangerous, for the figures I think will be found to be truly startling.

I would ask you, in the first place, to regard our coalfields in their true sense as enormous reservoirs of energy, which I cannot better compare than to the great reservoirs of water we have to supply our towns. There is however this great difference, that whilst in the case of water we make use of almost every drop we have stored, in the case of energy I shall, I think, be able to show you that our service mains are so leaky that we are only really making use of about one-tenth of this enormous stream of energy flowing from our coalfields, the other nine-tenths being lost to us for ever. Now, if we start off with the consideration of the coal in the depths of the earth, we find that our colliery engineers have to spend a considerable fraction of every ton to raise it from an average depth, say of 1,500 feet; but this is not so much their fault as that of the boiler-makers and steam engine builders, of whose shortcomings I hope to treat a little further on.

To raise one ton of coal from the average depth of 1500ft. would require of course the expenditure 3,360,000 foot pounds of energy, but this, of course, is absolutely unavoidable. This ton of coal of average quality would really possess the power of raising itself 2,000 miles high, but as our boiler-makers and steam engine builders can only make use of about one-tenth of it, we see that with the present efficiency of engines and boilers, and with a pit of 200 miles deep, it would take exactly the first ton of coal raised to bring the second ton to the top.

We will now continue our journey alongside this great stream of energy, a considerable fraction of which is being spent in transporting it from the coal fields to the various points where we can utilise it, but there is no means of estimating approximately the amount spent in this manner.

Now the first engineers we find manipulating an enormous portion of this mighty stream are the *Boiler-Makers*. In speaking of boiler makers I do not wish it to be understood that we look upon them as workers simply in iron and steel making structures of various forms to a given design. We can only truly regard them strictly as engineers, responsible for a certain amount of energy given into their hands, and for which we must hold them responsible.

In estimating their work I would not only estimate the amount of energy they handed on to the engine builders, but I would also hold them responsible for the *manner* in which it was done, for a man may do a considerable amount of work, yet kick up such a puther in doing so that he is a nuisance to all around him.

In taking the boiler-makers first I need not dwell at any length upon the efficiency of this branch of engineering, as Mr. Guthrie in his paper a few weeks ago dealt with it exhaustively. I will therefore only state here a few results.

If we take the ordinary Lancashire Boiler we find, from an

exhaustive experiment made under the supervision of Mr. Michael Longridge, in 1884 (report of which has been kindly lent me by Mr. Boswell) that the average actual efficiency of these boilers was 54 per cent, or in other words that the proportion which the quantity of energy received by the boiler-maker bears to the quantity which he hands over to the engine-builder is as 100 to 54. Unfortunately there was no means of saying what was the theoretical efficiency of these boilers considered as perfect heat engines, but with regard to the theoretical efficiency of a perfect engine, to which any apparatus using heat can be compared, I hope to treat a little later on.

We see, then, that our friends the land boiler-makers have attained to a maximum efficiency, compared with the total heat supplied, of 54 per cent, but this figure I fear is far in excess of the mean or average efficiency of land boilers.

Let us turn for a moment to marine boiler-makers, for here, I think, we find men working under a most healthy stimulus, for in the case of our great sea-going steamers the efficiency of the boilers and engines is of the utmost importance, in fact the very soul of the enterpise, whereas in the great spinning and manufacturing concerns the engines and boilers are quite secondary affairs in the success of the establishment.

Among our friends on the Clyde and the Tyne we see the very keenest competition for efficiency, and I think our constructors of land boilers and engines must admit that they are left distinctly behind in the race, for we find them now working commonly with pressures of 160 to 180 lbs. per square inch, with an efficiency of engine and boiler combined, represented by 1¼lb. of Welsh coal per I.H.P. per hour. If we take the marine boiler alone it would seem from the most recent data, taken from a paper recently read before the Institute of Mechanical Engineers on "Triple Expansion Engines," that the efficiency of the marine boiler has reached 80 per cent, evidently a considerable step in advance of our land boiler-makers.

Let us now, as it were, take another step alongside this great stream of energy on its way to work, but let us notice in passing that from 20 to 50 per cent of the total heat has been allowed to escape by the boiler-makers, so that our stream has been rapidly diminished at the very first step. Let us now see what the steam engine makers are doing; but this is an awkward problem, owing to the data relating to steam engines being so mixed up with that of the boilers. The importance of separating these two factors of the problem, or the entire separation of the duty of the boiler from that of the engine, I think cannot be too strongly insisted upon. They are almost invariably mixed together, so that if it is a question of efficiency of the engine alone which is being sought, we often find a

number of excuses and blame put on the boiler, and *vice versa*.

I think our first consideration should be given to the most prominent type of our district, the Corliss engine, whose comparatively high efficiency is generally admitted.

Turning again to the report before referred to, where most elaborate and instructive experiments were made on a pair of compound engines indicating abont 900 H.P., these results shewed that the heat utilized was 12 per cent of the heat supplied.

In quoting these figures there is one point we must not lose sight of which is important. These engines were supplied with steam at a temperature of 309 deg. Fah., corresponding of course to the pressure in the boilers, and the temperature of the ejection water was 106 Fah.

Now Carnot, an eminent French philosopher, has shewn that we can only get a definite amount of work out of a perfect heat engine working between two definite temperatures, such as this temperature of the boiler and the temperature of the ejection or refrigerator, whatever the mechanisms or apparatus may be, and that this efficiency is represented by the ratio which the difference of their *absolute* temperatures bears to the absolute temperature of the source or boiler in this case. As this question of the *absolute* temperature of a body does not often come into discussion, perhaps it may be of advantage (to my younger friends) if I digress for a moment to explain more fully what is meant by the absolute temperature of a body.

At the time when our Fah. thermometer was established as a standard it was well known that the temperature of melting ice and the boiling point of water were constant, and these were therefore marked freezing point and boiling point upon the scale, and the interval between divided into 180 equal parts, called degrees.

Using these as a basis and forming all sorts of combinations of substances for freezing mixtures, the lowest temperature they were able to obtain was 32 of these degrees below freezing point. This point was therefore named zero. But other experiments and considerations establish the fact that it is by no means the zero of temperature, the true zero being really about 460 deg. below this point, and the following is one of the considerations which has tended to establish this as the true zero of temperature.

If we take a definite quantity of a perfect gas and diminish its temperature 1 deg., keeping the pressure the same, we should find that its volume had diminished $\frac{1}{492}$ part of its original volume, and if we diminish its temperature another degree we ould find that its volume was again diminished $\frac{1}{492}$ part of its l volume, and so we might continue until our gas had zero. Hence if we took a volume of gas at a tempera- zing point we see that we could go on diminishing

its volume by the same fraction for each degree until we arrived at a point 492 degs. below freezing point or, 460 degs. below the common zero, and here the volume of gas we had would seem to have ceased to exist, having parted with all its heat.

These and other considerations which need not now be mentioned fix this point 460 degs. below the common zero, as the *absolute* zero of temperature, and temperatures reckoned from this point are called *absolute* temperatures, so that if we add 460 degs. to common Fah. temperatures we have at once the true scientific *absolute* temperatures.

If we denote the absolute temperature of the source of heat we are using by S, and the absolute temperature of refrigerator or condenser by T, then Carnot has proved that the efficiency of a *perfect* engine or the ratio

$$\frac{\text{Heat available}}{\text{Heat supplied}} = \frac{S-T}{S}$$

Taking the particular case of the Corliss engines previously mentioned, the temperature of the steam from boilers was 309 degs. Fah., and the temperature of the ejection water from the condenser was 106 degs. Fah. If we now calculate the *absolute* temperature of the source we find it has 309 + 460 = 769 degs., and the *absolute* temperature of ejection we find as 106 + 460 = 566 degs. Then applying Carnot's principle we see that the utmost we could possibly get out of these engines would be

$$= \frac{769-566}{769} = \cdot 27$$

or 27 per cent of the total amount of heat supplied to them.

As the expression of Carnot for the efficiency of a perfect engine is one which can be applied to any heat engine in which the temperature of the source of heat, and that of the ejector can be determined, no matter what the construction, it becomes one of the most important expressions we can meet with in engineering work, and therefore at the risk of being a little tedious I will stop for a moment to discuss it.

If we examine the expression mathematically, we see at once that we can never get this expression equal to unity so as to get the whole of the heat converted into mechanical energy, unless we could reduce the temperature of the refrigerator or condenser to *absolute* zero, but as this is a physical impossibility we can only see what are the directions in which we really can move.

To increase the value of this fraction or in other words to increase the efficiency of our engines, we must either increase the temperature of the source, which means the pressure in our boilers if worked by steam, or diminish the temperature of ejection, but of these we see that for the same number of

degrees of temperature it would pay us best to diminish the temperature of ejection. When we have gone as far as possible in this direction our only resource is to increase the pressure in our boilers, but this does not increase the efficiency of engines so rapidly, as we are increasing both the numerator and the denominator of the fraction at the same time.

A curious point about this expression of Carnot's is that the fundamental views of this French philosopher as to the real nature of heat have been found to be entirely erroneous, yet the reasoning by which he established this expression was absolutely perfect, and found to hold entirely even under the modern views of heat.

Returning again to the Corliss engines under consideration, we find that when their actual efficiencies were compared with the efficiencies of a perfect heat engine, receiving and discharging heat at the same temperatures, that their efficiency was 41 per cent of that of a perfect engine working between these temperatures. These engines and boiler together were found to be using 2lb. of coal per H.P. per hour, and this we must remember is a comparatively high efficiency, for if we turn to the reports of our steam boiler associations, we find that the averages taken over a considerable number of engines in regular work show that the consumption of fuel by the following types of engines to be per I.H.P. per hour: —

1. Compound engines, condensing ..... 3·66 lbs.
2. Single cylinder, condensing ..... 5·88 lbs.
3. Single cylinder, non-condensing ..... 7·95 lbs.

These show very plainly that the non-condensing or high-pressure engines, as they are sometimes called, are extremely wasteful, and ought where possible to be abolished.

We will now turn to the marine engine-makers and see what they are doing.

Anyone, I am sure, who has studied the recent paper which has been read before the Institute of Mechanical Engineers cannot but be struck with the great step in advance which the Triple Expansion Engines recently introduced have made over the double expansion or compound engine, this being as great or greater than the advance formerly made by compounds over the single cylinder engines.

We may gather some conception of this great advance when we consider that in one Australian steamer, the "Lusitania," the consumption of fuel was reduced from 52 tons to 37 tons per day, or a gain of 29 per cent, saving on a round voyage of 80 days 1,200 tons of coal, which in the case of steamers represents a double gain, being first that of the coal and afterwards that of the increased carrying capacity for cargo. Some marine engineers seeing these remarkable results have already made

a further step to quadruple engines, bringing the coal consumption down to about $1\frac{1}{8}$lb. of coal per I.H.P. per hour.

Let us now in our journey alongside the great stream of energy step aside a little to see what is being done among *gas engines* towards the more economical production of mechanical energy.

Among all the various gas engines now in the market, with their very variable efficiencies, I think it is now everywhere admitted that the "Otto" engine is yet the most perfect and efficient of the whole family, and will therefore confine myself to the con-sideration of its efficiency.

The consumption of ordinary illuminating gas by this engine varies from 25 to 18 cubic ft. per 1 H.P. per hour according to size of engine and the quality of gas used, but we may safely take 20 ft. per hour as the general average. Now 1 cubic ft. of good average gas at atmospheric pressure and mean temperature, develops on combustion about 620 units of heat, therefore the total heat supplied to the engine per I.H.P. per hour would be $620 \times 20, = 12{,}400$ units, but the units of heat required for one I.H.P. per hour are

$$\frac{33{,}000 \times 60}{772} = 2{,}564$$

the number 772 being the mechanical equivalent in ft. pounds of 1 unit of heat.

Therefore the ratio

$$\frac{\text{Heat utilised}}{\text{Heat supplied}} = \frac{2{,}564}{12{,}400}$$

$$\text{Or actual efficiency} = 20{\cdot}6 \text{ per cent.}$$

Considering the economical use of heat this is the true test of its efficiency, but if we begin to test the efficiency ef the mechanism we employ, as a heat engine working between two definite temperatures, we can again apply Carnot's principle, and see what would be the efficiency of a perfect gas engine working between the estimated temperatures of combustion in the cylinder 3,000 deg. Fah. of absolute temperature, and 1,250 deg. Fah. as the temperature of discharge of the gas, we have

$$\frac{\text{Heat available}}{\text{Heat supplied}} = \frac{3{,}000-1250}{3{,}000}$$

Maximum efficiency possible would be = 58 per cent.

Hence we see that under the present conditions, the "Otto" is working with an efficiency of 38 per cent of that of a *perfect* engine working between the same temperatures.

In an actual experiment conducted to test this, it was found that 29 per cent of *available* heat was effective, in view of Carnot's principle limiting the amount of heat available. Of the remaining heat, 69 per cent was shown to be carried off by the water

jacket to the cylinder, and under 2 per cent of loss was due to direct radiation.

I will return to this question again in the general comparison of the efficiency of heat engines.

By using the Dowson gas apparatus, it appears that 16·25lb. of coal are required to produce 1,000ft. of this gas, but this gas is weaker than the ordinary illuminating gas, and requires about four times the amount to produce the same effect in the gas engine as ordinary illuminating gas; therefore it takes 65lb. of coal by the Dowson process to produce the same effect as 1,000ft. of ordinary illuminating gas. Again, to produce 1,000ft. of illuminating gas requires 224lb. of cannel coal, so that for this purpose 65lb. of coal produces the same effect by the Dowson process as 224lb. by using ordinary illuminating gas. Further, we know that 1,000 cubic feet of ordinary gas produces 50 H.P.; therefore this 65lb. of coal produces 50 H.P., or at the rate of 1·3lb. of coal per H.P. per hour. This Dowson process has now been adapted to make gas from ordinary gas coke, with the remarkable result which shows that 1·4lb. of coke will produce in the "Otto" engine 1 H.P.

Having now considered the chief various means of producing mechanical energy and their relative efficiencies, I will now pass to the consideration of the transmission of energy; but before doing so, I would refer for a moment to a curious fact connected with the friction in steam engines which I came across in hunting up various figures for this paper.

Prof. Thurston has recently read a paper before the American Society of Mechanical Engineers, in which he gives the results of a long series of experiments on steam engines, which establish the curious fact that the power absorbed by the friction of an engine is practically *constant*, and not varying with the load as is generally supposed. This shows the importance of using large engines and working them well up to their full power, for then the percentage loss on the whole is considerably diminished.

We have now arrived at the point where our millwrights take up the energy handed to them by the engine maker, and of the various forms of the transmission of energy we have several prominent types, such as, starting from the prime mover:

Transmission by belting and shafting.
,, ,, rope pulleys and shafting.
,, ,, gearing and ,,
,, ,, electricity.

We here come to that branch of engineering in which, until recent years, I fear there has been the least scientific method applied to the work in thoroughly testing the results obtained

by the various systems. The insurance of engines as well as boilers has, however, in recent years, led to considerable improvement, and we have now in our midst a staff of trained men who are thoroughly experienced and ready at any moment to test the results of any system in a thoroughly independent and unbiassed manner. So many of the experiments conducted by private firms being influenced by the result which they *desired* to obtain. We have therefore a vast mass of information accumulating in these Insurance Offices which I should much like to see more fully brought before the world, for it is of the utmost value.

Having appealed to a gentleman who has had considerable experience in the independent testing of the various methods of driving, I am enabled to give the following as a general summary.

Among our modern cotton mills requiring about 800 to 1000 H.P., it is found that the energy absorbed by friction varies from 20 to 30 per cent of the whole amount transmitted, rarely falling below 20 per cent, but sometimes reaching in bad cases as much as 35 per cent.

It is extremely difficult to find two mills working under entirely similar conditions so as to make comparisons, but in cases where changes have been made in the actual driving in the same mill, the different systems employed can be compared.

Taking the three prominent systems of *main* driving it is found that strap driving absorbs about 5 per cent more energy than spur gearing, whilst rope driving absorbs about 10 per cent more.

There is one method of transmitting energy that has not yet been largely used, where considerable quantities are required, and that is by *electricity*. It is, however, capable of considerable developement, and there have been many experiments of recent years to determine the real efficiency of this means of transmitting energy,

A few years ago Sir W. Thomson investigated the conditions under which the energy of the falls of Niagara could be transmitted to such towns as Montreal, Philadelphia, and New York, and he found that with a copper wire ½in. diameter, and a potential of 80,000 volts that energy to the amount of about 26,000 H.P. could be transmitted a distance of 300 miles with a loss of but 20 per cent. This loss of 20 per cent being due, of course, to the heating of the wire caused by the resistance to the current passing through it. This exceedingly high potential would be extremely difficult to handle with safety by unskilled persons, and would require entirely special arrangements to ensure safety. But this would doubtless be overcome, as Sir W. Thomson remarked that in an electric workshop this would really be no more dangerous than a circular saw.

An experiment in which the conditions were more in accordance with what is found in every day practice was conducted at Paris, during the spring of last year. The object of the

experiment was to shew the possibility of transmitting a force of 200 H.P. for a distance of 56 kilometres, or about 35 miles, with a loss of 50 per cent. The actual experiment shewed a result of about 45 per cent. It was, however, shewn as probable that with improved appliances an efficiency of 50 per cent may be relied upon over this distance.

An extremely interesting case of the electral transmission of energy I saw in Paris a short time ago, where a large firm of engineers had applied it to their large foundry jib-crane, lifting I should think 15 to 20 tons. As far as I could follow the arrangement by an inspection from the floor, a small dynamo seemed to be applied to each of the motions required for the crane. The whole of the movements were controlled by a man on the floor standing alongside the pillar with a simple handle and switch-board, so that he could send the current to any one of the various motions with the utmost ease and simplicity,

And now, gentlemen, having at last got our energy into our workshops and distributed to our machines, how do we, as constructive engineers, deal with it. I fear there is a very considerable leakage takes place actually in our hands as it were. Take, for instance, the familiar case of the cutting of metals and what a vast amount of energy is here wasted. If we take a walk round a number of workshops one cannot but be struck with the primitive cutting tools which are being employed, thoroughly convincing one of the waste going on, for we find tools being used which are wasting at least 50 per cent of the energy supplied, whilst over them we shall probably find men looking quite bland and utterly unaware of the atrocity they are perpetrating.

If we were to begin to examine the various machine tools in our workshops as to their efficiency, we should open up an extremely wide and interesting question; but without undertaking a very great number of experiments, with the dynomometer involving considerable expense, this could not be arrived at. It would be remarkably instructive to know the number of foot-pounds actually absorbed by various machines in cutting away a definite quantity of metal, say 1 cwt., as well as the time employed.

Perhaps you may think that I have been very critical of all the various branches of engineering except my own; but, in the absence of strictly scientific data upon which to base our calculations, I feel considerable diffidence in the matter lest any opinion of mine, based largely upon observation, might not be taken with a considerable grain of salt as a "trade" statement. I will however venture an opinion which every hearer may take with as much salt as he considers necessary, and that is, that the efficiency of the modern machine tool has within

the last 20 years been increased at least 30 to 50 per cent on an average.

Digressing for a moment to speak of the general efficiency of the machine tool from an economical point of view, apart from the amount of energy required to drive it, we ought strictly to regard the man attending it and the machine as a whole, and consider the amount of work produced in a given time, for the time taken in actual cutting is not the *chief* item in the question, but the time occupied in setting work; the average time occupied in most engineering shops in setting the work being twice the time occupied in actual cutting or operation.

This can easily be tested by walking right round the shops and just marking down in passing whether a machine is actually in operation or not, and it will be found that only about one-third of the machines are actually cutting, whilst the remaining two-thirds are either setting or stopped for some reason or other, thus shewing that the average actual cutting time is only about one-third of the whole.

For the purpose of shewing graphically the relative efficiencies of these various heat engines, I have constructed diagram No. 1, to scale upon which are marked on vertical lines the relative efficiencies of each for the purpose of shewing the relative proportions of that vast stream of energy which is lost in the hands of the various branches of engineers.

Let us examine the boilers for a moment first and consider briefly what is the maximum efficiency of a perfect boiler, and this is easily done by applying Carnot's principle. The maximum temperature at what the boiler receives its heat is from several considerations estimated to be about 4000 degs. Fah. of absolute temperature, and the lowest temperature at which we can economically discharge the products of combustion would be the average temperature of the air say 50 deg. Fah. ordinary scale or, 510 deg. Fah. absolute scale, therefore applying Carnot's principle

$$\frac{\text{Heat utilisable}}{\text{Heat supplied}} = \frac{4{,}000 - 510}{4{,}000}$$

or, heat utilisable is 87 per cent of the heat supplied.

We see also from the diagram that the marine engine boiler is rapidly approaching perfection, being 80 per cent of the total heat applied (but I may here mention that of this figure I have considerable doubt) whilst the land boiler is but about 54 per cent. I think a few general observations may here be ventured upon without raising strong opposition from any particular section of our friends; but in speaking of the work done by different branches of engineering from a more strictly scientific point of view, I would not desire to ignore for a moment the great difficulties surrounding the practical solutions of the various problems

which a general review brings out. These difficulties I fully appreciate, and the vast amount of real earnest work going on I warmly recognise, but I would ask you to look at these points as *difficulties* only, and not as problems which it is impossible to solve. I am led to make these observations from the experience I had a few weeks ago when I ventured to make a few remarks on boiler-makers' monuments in the form of long chimneys, when I was reminded of innumerable difficulties, of which I was fully aware, but which as in the case this evening one cannot stop to investigate. With reference to these long chimneys one cannot but be struck with the extremly clumsy means they are of obtaining a draught, and at the same time a very wasteful one. Mr. Guthrie, a few weeks ago, shewed us that 20 per cent of the total heat was lost by the chimney.

We can however easily shew what would be the loss in a perfect boiler if we allow the products of combustion to escape at a higher temperature, say 700 deg. Fah., ordinary scale. By applying Carnot's principle for them we have in absolute temperature,

$$\frac{\text{Heat utilisable}}{\text{Heat supplied}} = \frac{400 - 1160}{4000}$$

or heat utilisable is only 71 per cent of heat supplied, thus shewing that in a perfect boiler the loss due to the creation of draught by this means would be 16 per cent of total heat supplied, much more in fact than what we are now obtaining from the engines.

I certainly think that the next step in boilers will be the universal use of the hot blast for supplying air to our boilers, producing very greatly-increased efficiency n fact an experiment is now being tried upon a large ocean steamer with the use of the hot blast, and the results are I believe proving very remarkable, but the data are not yet sufficiently complete to enable its efficiency to be stated.

The leakage of energy due to these long chimneys is very serious, and the point which to my mind seems to call for the most immediate attention. As I have before said, I fear we have come to regard these chimneys as a sort of absolute necessity in our midst, and come to regard them with the utmost composure, yet if we saw an engineer endeavouring to produce blast for his cupola by such a means we should laugh at him with derision.

I think it is high time that these hideous structures (erected all over our country), representing the unscaled heights of boiler engineering, should be swept away for ever, and that the whole process of coal-burning should be treated as a chemical one, and that the whole products of combustion should be treated chemically and utilised without having to pour them

over the whole country, poisoning everything around them, and producing that grimy, repulsive appearance of so many of our large towns.

If we consider these boilers with reference to the conservation of energy, we should be able to prepare a balance sheet shewing on the one side the total energy of the fuel supplied, and on the other, we could prepare the account shewing that this was exactly accounted for by the quantity stored in the steam, together with the quantities escaping by radiation and by way of the chimney, and what is lost in the ashes, but not one single fraction more than what we supplied shewing that there has been no creation of energy, simply transformation.

Let us now again refer to diagram No. 1 and examine the efficiency of the various engines. The top line shews the efficiency of a perfect engine, assuming that it was taking steam at a pressure of 200lb. per square inch, and discharging it at a temperature of the surrounding atmosphere about 50 deg. Fah., converting the corresponding temperature into *absolute* temperatures and applying Carnot's principle.

$$\frac{\text{Heat available}}{\text{Heat supplied}} = \frac{842 - 510}{842}$$

thus shewing us that by means of steam we shall never, *when working between these temperatures*, be able to realise more than 40 per cent of the heat supplied even in a perfect engine.

These considerations must suggest to many minds very grave doubts whether in struggling to develope the steam engine we are really on the best lines. Although the efficiency of a perfect steam engine is very low, yet if we examine the diagram (which is drawn to scale) we shall see that the present engine falls even miserably short of it, for we see even with the more perfect triple expansion engines, are but utilising about 15·9 per cent of the total heat supplied, whilst the Corliss are but utilising about 14 per cent of heat supplied.

Using the same scale, I have also marked on this diagram No. 1, the comparative efficiency of the Otto gas engine, but only in dotted lines, because, although we are certain of the efficiency of the Otto gas engine being strictly 1.3 lbs. of coal per H.P. per hour with the Dowson gas, yet comparing the manufacture of gas with the production of steam, it would seem as though only about 46 per cent of the heat supplied in making gas was retained in the gas ready for use in the engine. But from an economical point of view we cannot consider the gas as the only product of gas manufacture in the same manner as we consider steam from a boiler. From the diagram we see that the actual efficiency of the gas engine is already ahead of that of our best land engines, and I cannot but think that this is

the engine of the future, for not only is it already ahead, but it also contains much more virgin ground for improvement.

For the purpose of comparing these various heat engines by by the light of Carnot's principle, I have constructed diagram No. 2, in which from a comparison of areas we are able by the eye to judge of the different efficiencies, assuming them to be perfect.

There is one point about Carnot's principle which it is important to notice, for although it will at once tell the performance of any perfect heat engine working between any two temperatures, yet it does not say that these are the *best* temperatures at which to *deal* with the heat, far from it.

Referring to diagram No. 2, the vertical lines represent degrees in temperature reckoned from the absolute zero, 460 degs. Fah. below our common zero., this point being marked O. The top of this (A) represents the estimated temperature produced in the combustion of coal or, the highest *temperature* at which we can naturally become possessed of our energy in the form of heat, so that we can regard this line as the scale of an immense thermometer. I have marked also the average temperature of the air about 50 degs. Fah. ordinary scale or 510 degs. absolute scale by the line B C.

If our engine was able to take the heat at a temperature of of 4,000 degs., and the temperature of the condenser was absolute zero, we should then, and only then, have all the energy stored in the coal available for mechanical work, and we might represent this by the triangle A O M.

If we now mark off at D the temperature of 840 degs. corresponding to an engine working at 200lbs. pressure and *assume* that it discharges its unused heat at a temperature of 560 degs. or the point C., then the triangle D C B represents the fall in temperature or D M B, which is the same area; hence by Carnot's principle, the ratio of D C B, or D M B to the triangle D M O, represents the absolute efficiency of a perfect engine working between these two temperatures.

Let us now mark off the gas engine, taking its heat at the point G, or 3,000 degs. Fah., and discharging the unused heat at the point F or 1,250 degrees, which is the point at which it is now usually discharged, then the triangle G F E would represent the fall in temperature, and the ratio of the triangle G F E or G M E (which is the same area) to the triangle G M O, represents the absolute efficiency of a perfect gas engine working between these temperatures.

Should we however be able to so utilise the heat as only to discharge the unused heat at the temperature of the atmosphere, or point C, as we have assumed in the case of the steam engine, then, the triangle G C B, or G M B (which is the same area) represents the fall in temperature, and the ratio of G M B to

the triangle G M O represents the absolute efficiency of a perfect gas engine working between these temperatures.

$$\frac{\text{Heat available}}{\text{Heat suplied}} = \frac{3{,}000 - 510}{3{,}000} = \cdot 83$$

This shews us that whereas in the steam engine, with an assumed maximum pressure of 200lb. per square in., we have only a possibility of 40 per cent efficiency, we have in the gas engine a possibility of about 83 per cent.

Of the performance of the millwrights, with their appropriation of about 30 per cent of the energy handed to them for transmission, I am not able to say whether it is possible to save much. Certainly it seems a large percentage to be taken from our greatly-diminished stream of energy. By driving through shafting and pulleys, carefully balanced and carried by the latest swivel or compensating bearings, there must certainly be a great gain over the cumbersome shafting, pulleys, &c., of the old plan, for which I am surprised to find there are even yet customers for.

Of the energy lost by the employment of defective cutting tools, amounting to about 50 per cent, this, I am sure, could all be easily saved, but the difficulty lies in rousing the minds of engineers to realise the fact.

What seems to be wanted in all our engineering work is that we shall bring greater scientific knowledge to bear upon our work, and with it a more truly scientific habit of mind, which estimates and measures everything, and takes nothing for granted however plausible it may seem to be. In the erection of gearings, &c., and the thorough testing of the efficiency of machinery, we really want a far greater use of the dynamometer, so that accurate determinations may be made and tabulated, which would very quickly settle many of the disputes as to the best method of driving, &c., and carry the questions out of the reach of opinion into the clear region of scientific fact, about which there can be no dispute.

I hear that a new dynamometer is likely to be brought out in this country, in a very portable and convenient form. Should this become popularised among engineers we shall then be on the threshold of much accurate work which is greatly needed among engineers, for it is high time the age represented by the "rule of thumb" had gone by for ever.

Having now completed the general survey of this mighty stream of energy on its way to work, and which we never see increasing, but so rapidly decreasing, you may perhaps ask, seeing that energy is indestructable, what becomes of all the energy which leaves our coal fields? It is all dissipated as heat at a low temperature, and is therefore in a condition which renders it entirely unavailable.

We may truly regard this as degraded heat much as we regard the water in the tail race of a water-wheel where we know that its capacity for doing work has entirely ceased. This tendency towards the dissipation of all our energy should naturally lead us to consider the condition of our stores, and what are our prospects for the future.

The present abundance of coal often leads men to regard our stores as being practically inexhaustible, but it is a terribly false position, and one for which we as engineers shall be held responsible by future generations.

The exceptional richness of our stores in this country has led to very considerable waste of our energy, we having, as it were, simply used the cream and cast away the milk. This is a condition of things which cannot be continued with impunity, and one cannot but be reminded of the sound maxim taught us in youth that "wilful waste makes woeful want."

Formerly our supply of coal was an unknown quantity, but the Government Geological Survey of England has practically determined the amount of coal we have, and Mr. Hull, an eminent geologist, from careful estimates, places it at 83,544 millions of tons. We have no conception mentally of this figure, but we may get an idea of one million tons, for a cubic yard of coal is almost exactly a ton. A bed of coal, therefore, 20 yards wide and 1 yard deep, reaching from Manchester to Liverpool, would contain about one million tons.

When we consider that our output of coal has now reached 100 millions of tons per year, we see what an enormous drain is being annually made upon our stores. Some may object and say that any calculation of total quantity is impossible, as the depth to which we can go has never been determined.

There is one consideration, however, arising from the increase of temperature as we descend, which practically limits the depth, and all geologists are agreed that 4,000ft. is the limit, beyond which we cannot go.

The estimate of time we may expect our coal fields to last depends very largely upon the question whether the same rate of increase of consumption is maintained in the future which has happened in the past. If we consider that we have reached the maximum consumption, then we might expect our coal fields to last some 800 years; but, if we consider the yearly increase which there is every reason to expect, then we must face the fact that our coal fields will be exhausted certainly within 200 years.

These facts throw upon us, as engineers, an enormous responsibility, for the future welfare of our country is very largely bound up with the question of the efficiency of our engines, for there can be no doubt of the fact that our engines are the very motive power of our country.

Bearing these facts in mind and looking to the diagram No. 1, one cannot but feel somewhat humiliated to think that the small stream of energy shewn on the right, and which is but about one tenth of the whole, is all that we boastful engineers of the nineteenth century are able to utilise from that enormous stream shewn on the left, and which is flowing from a reservoir in which the amount is exceedingly limited.

Gentlemen, need we not as engineers and Englishmen brace ourselves up to the battle, and arming ourselves with the most accurate knowledge of the problem, go on our way determined to utilise more of that vast stream of energy which nature has so generously provided for us.

DISCUSSION.

The President remarked that the paper which had just been read to them would be a valuable contribution to the records of the Association, and especially useful to those members who were users of various forms of energy. The statements, however, which had been made from time to time respecting the electrical transmission of energy, he thought, might be fairly questioned. It had been asserted at various times that it could be transmitted 50 miles at a loss of 50 per cent., and with that assertion he frankly told them he could not agree. If they compared the loss accruing from the electrical transmission of energy with that of the hydraulic transmission of energy, in his opinion the comparison would be very much in favour of transmission by the latter method. He could call to mind several instances where hydraulic power had been used to transmit energy from one pump to another, or to a hauling engine where the loss in each instance though a thousand yards had only been 10 to 15 per cent.; and he believed that energy could be transmitted thirty or forty miles by hydraulic pressure, with only a loss of 15 per cent. of the total energy, if the pipes were properly proportioned. Electrical engineers had a very nice way of using certain terms, as for instance when they spoke of a copper wire ¼ inch, in diameter, when, as a matter of fact, the term rod would be much nearer the correct expression, and he need not tell them that the capital account of a copper rod fifty miles long would be rather startling. He had occasionally calculated the cost of the electrical transmission of energy, say from some of the waterfalls in the country to the nearest populous town, and the cost of the copper rod dynamo, together with the wear and

tear would be enormous, and infinitely greater than if hydraulic power were used.

Alluding to the probable exhaustion of our coal supply, he said he did not believe that if such a thing came to pass that it would be so disastrous as was constantly being predicted. And why? because it would not cost so much, or at least, not more to bring coal from the Canadian coalfields than it did now to bring it from Newcastle to Manchester. At the present time it did not cost more to transport timber from Norway to England than from district to district in the latter country. Under those circumstances he was of opinion that so long as they did not neglect technical education, and endeavoured to educate the artizans to a knowledge of where materials were to be found, they need not fear the loss of future supplies. All this being done, as well as keeping our shipping transports in high efficiency, it was immaterial if the coal were at Bolton or Russia, or wherever it might be.

Mr. Boswell protested against the charges made about the boiler-makers, which he said were utterly unjustifiable. The lecturer lost sight of the fact that the boiler-maker was not a *steam producer*, but simply the maker of the boiler, and further that he did not build the chimney. It certainly would be deemed a little presumptuous on the boiler-maker's part if he were to cross question his customers on the style of their chimneys. As regarded the manufacturing of boilers for high pressure, he might tell them that it was merely a question of demand, and, if required the boiler-maker could make boilers of plates of any thickness, and to stand the same high pressure as those made by the marine engineer. If there were any difficulty it would be in transporting a boiler of such a thickness, due to the inadequency of the roads, but of course a marine engineer building his boilers on the waterside, was in no such dilemma.

Perhaps one of the reasons why boilers in many instances were not as efficient as they might be, was because they did not have the requisite cleaning, as in his experience, there was nothing more neglected than that duty. Again in many cases boilers were evaporating over 10lbs. of water, while some cases were known of over 11lbs. being evaporated. The boiler was therefore not so wasteful as engineers would have them believe, and if the maker of the boiler could have his own way, it would be even less wasteful, and he thought the per centage of 54 as shewn was altogether too low for first-class boilers now in use. Seeing the coal was consumed under the boiler, it was an easy matter to book all loss against the boiler, though if the amount of water evaporated and steam used by engine were taken into account, the result would be altogether different.

Alluding to the data regarding marine engines given by the

lecturer, Mr. Boswell said those data were never given unless they were extraordinarily good, whereas in the case of general works' engines, they were given in the first instance previous to some contemplated alteration, probably ordered or advised by an Insurance Company, and then afterwards for the purpose of pushing trade, and thus they had the very best and the very worst results respectively.

Mr. Joseph Nasmith observed that the point to which he wished to direct their attention, was the question of friction inside a cotton mill. For some years past a great deal of attention had been paid to the efficient working both of steam boiler and engine, and in the latter case indications had been taken more regularly with the object of minutely detecting its defects, and the result was that the steam engine had now become a most efficient instrument. During that time however, no attention had been paid to the gearing inside the mill, and it had been allowed to run in a condition which was a bad one, and certainly one which was taking up a large amount of friction. Now did it not strike them as being one of the strangest things on record, that while every attention had been paid to the instrument that produced the power, no means had been taken to see if the power was being properly utilised at the point where it was taken off. The lecturer had referred to a form of dynamometer which was about to be introduced into this country. He (Mr. Nasmith) believed one of the wants of the age was an efficient dynamometer; one which could be fixed easily and read with facility, and by which they could tell what every line shafting was doing in a cotton mill, and which also could be attached to every machine in order to ascertain its work.

Now the dynamometer referred to and which he presumed to be the Emerson Power Scale, could be hung on a line of shafting, and it would indicate what that shafting was doing, while it was equally applicable to a spinning frame or any machine, and it would indicate its true amount of work. Amongst other experiments it had been applied to two spinning frames of identical construction and spinning same counts, working alongside each other, and the result clearly showed that 1¼ horse-power and 3½ horse-power was being used to drive each frame respectively. From this instance it could readily be imagined that in a mill, say of 80,000 spindles, it was not possible to find out where any waste was occurring unless the power could be localised. The question then of finding out the loss by friction in a mill, or any other place where power was used, was of primary importance, and deserved the attention both of engineers and of steam power users. *Apropos*, of this subject he anticipated that during the next session of the Association he might

be able to present to the members the results of certain experiments in the use of the dynamometer.

Referring to electrical efficiency, Mr. Nasmith said it seemed to be lacking in this respect: if they were going to adopt electrical transmission it was necessary to produce the electrical transmission which gave them the power, unless they were so placed that they could raise that power by some natural means, say of a running stream, or waterfall, or anything of that kind. They were bound in the first case to put as much power on that machine to produce the efficiency as could be got out of it. As regarded the economy of the arrangement he did not think there could be two questions. There was not the slightest doubt to him that some such scheme as the Hydraulic system being now carried out in Liverpool, or the Compressed air scheme in Birmingham for the distribution of small powers was an excellent arrangement for large towns, and in the carrying out of such arrangements it would tend to the benefit of the community at large if promoters of such schemes and municipal corporations would join hands and endeavour to bring them to a successful issue.

Mr. A. Rea observed that the essayist charged the millwrights with using 30 per cent. of the energy supplied them in transmitting power from the prime mover to the machines driven. He should like to ask did this refer only to shafting and gearing or did it include the steam engine as well. If it did not there must be some mistake in the data given, as the energy lost would be far too high for mere transmission by any of the ordinary forms of gearing in general use. He might mention to the meeting that on testing the loss of power by transmitting the load from the prime mover to a second shaft through a pair of spur wheels the loss was about 2 per cent. for one remove. The loss of energy in a textile factory arose more from the nature of the work to be done than from any fault of the millwright, seeing the number and variety of the machines to be driven and their distance from the prime mover; to make this loss as small as possible, there was no doubt that, having all the connections in good order, must be a decided gain or advantage. To his mind, however, the greatest loss arose in the motor itself, arising, as all know from a variety of causes all acting in the same direction, such as the nature of the energy supplied not being a permanent gas; the friction arising from the several parts of the machine; the problem of having to change lateral motion into rotary, necessitating the use of a fly wheel, &c., though essential for giving uniformity of motion, yet absorbed energy. He should like to ask Mr. Dixon if he considered the driving of the motor and connections all loss of energy. Should some allowance not be made for the *vis viva* imparted to the engine and connections

which would materially reduce the 30 per cent. dissipated.

Again, he should be glad if Mr. Dixon would inform them how he based his calculation in reference to the tall chimney *versus* the fan, or other mechanical blast as regarded the efficiency of the latter over the former. He could not but think that the lecturer was rather severe on the chimneys, by saying that they were hideous monuments to the want of genius on the part of our boiler-makers, as he believed a great deal might be said from a sanitary point of view in favour of the chimney. Again, the chimney was the most natural and simplest plan for performing the work it had got to do. He thought further that it could be demonstrated that the chimney with all its faults, for land furnaces was the cheapest and most efficient for all general purposes.

Mr. H. Guthrie in proposing a vote of thanks to the lecturer, remarked that he did not believe there was so much to be gained from chemical combustion as was commonly imagined, that was to say, having the minimum amount of oxygen or air mixed with coal to produce combustion. In the matter of the transfer of heat it was not always so much a question of intensity as of quantity, and as for quantity, that would be the same whether the combustion took place in chemical proportion or under the ordinary circumstances. Of course, we must admit, that the proportion of loss by the chimney would be greater the lower the temperature of combustion; at the same time it must also be admitted that (taking a practical view of the question) were the temperature of the furnace raised much above what it now ordinarily works at, a much greater loss would be incurred by the very rapid destruction of the plates of the firebox and the grate-fittings, indeed the repairs incumbent upon so high a temperature would be enormous. The furnace flue is already the most difficult to maintain, and although great improvements have been made in the way of elastic joints to allow of expansion and contraction, these joints would not be equal to the increased strain and movements due to a much higher temperature. In conclusion, he begged to propose that the best thanks of the meeting be given to Mr. Dixon for his very able and interesting paper.

Mr. J. Hartley, in seconding the vote of thanks, said, he would like to ask the lecturer in reference to the remarks on the temperature of the admitted steam and the temperature of the injection water of the Corliss engine, whether in the particular instance quoted the cylinders were steam jacketted or not, because this might have a bearing on the case?

As regarded the comparison made between the marine engine and the land engine, he contended that such comparison was not

right and for this reason: it was very easy to say a marine engine was using 1½lbs. of coal per H.P. per hour, and that a land engine was using as much as 2 to 2½lbs. But in considering that comparison they must remember that our cotton mill engine only worked during stated hours, having two stoppages during the day, and as a rule, the commonest and cheapest of fuel was used; the cylinders were not steam-jacketted and only a moderate boiler pressure (80lbs.) was carried, whilst the marine engine worked sometimes for weeks together without stoppage and in this case a very high boiler pressure (150lbs.) was carried, the best of fuel used and all the cylinders were steam-jacketted. Again on land, besides coal being used for raising steam during the time the engine was working, coal was required in the morning to get up steam as well as to heat the flues to the necessary temperature during the day. All these little extras being taken into consideration, and duly allowed for, he believed the land engine would not fall very far behind the marine engine in efficiency. He had in his possession the results of some tests made with an ordinary compound engine (the cylinders unjacketted) taken a short time ago, in which the coal consumption *during its actual work* was only 1·6lbs. per H.P. per hour, which was very satisfactory indeed. While referring to marine engines, he might remark that in the majority of those engines there were very large clearance spaces in the cylinders (and these would not compare favourably with land engines either for efficiency or economy) and unless the steam was compressed in those clearance spaces at each stroke, a great loss occurred; from a number of diagrams he had seen, however, he found that this important fact seemed to be entirely overlooked. It was simply a question of compression.

Respecting the power absorbed by friction in cotton mills, and especially at old mills, he might say that a great deal of this might be attributed to the uneven flooring, but which might be neutralised by efficient lining up and resetting of the machinery and shafting. Certainly, if more attention were paid to that point in endeavouring to find out the reasons for an undue consumption of fuel, instead of attributing it to the inefficiency of the engine or boiler, the result would in many cases be apparent in a lesser coal consumption.

Referring to the loss of thirty per cent. by friction alluded to by the lecturer, he might say that he knew of several instances where the loss by friction only amounted to twelve or fifteen per cent., which, in his opinion, was a very good percentage.

The vote of thanks was carried with acclamation.

Mr. Dixon said he had been pleased to find that the paper had aised so much discussion, indicating as it did a growing interest

in the more strictly scientific view of some of the problems found in engineering.

With reference to the doubt cast by the President on the statement as to the Transmission of Energy by Electricity a distance of 50 miles with a loss of only 50 per cent., he would point out that the actual experiment referred to in the paper, was conducted at Creil, near Paris, last spring, and reported among other journals by *Nature*, of 12th August, 1886. These results were fully authenticated and did not he thought admit of any reasonable doubt. With reference to the transmission of energy by Hydraulic Pressure or Compressed Air, for comparatively short distances, he fully agreed with the President, but for greater distances, such as the case of the Niagara named, he thought that electricity would be found to have a decided advantage, and it might here be mentioned that when Prof. Thomson investigated this problem, he took fully into consideration the very obvious question of cost of copper wire or rod which would be necessary. From the President's view of the coal question, he could not but express his entire dissent and was somewhat surprised to hear it advanced when they saw many of their large industries finding themselves already seriously handicapped by being situated in an inland town. But this opened up such an extremely wide question that in reply, he would simply reverse the positions, and ask the question, where at the present time could they find an important industry, such as the iron industry prospering in a foreign country which was only supplied with coal from England ?

With reference to Mr. Boswell's remarks, he must say that he could not at all see where the cause for his strong feeling came in. He (Mr. Dixon) endeavoured to view Boiler-makers from the higher standpoint as *Engineers*, responsible for the whole process of steam production and not merely as kettle makers, workers in iron and steel, as Mr. Boswell would seem to regard them. Concerning the long chimneys, he could not think that anyone built them as " things of beauty," but simply because the present boilers *required* them. Mr. Boswell seemed to be of opinion that the data given were not fairly selected, the best being taken in some, and the worst in others. This, he must say, was entirely erroneous ; at least it had been his endeavour to take only the *best* authenticated in each branch of engineering, so as to arrive at the degree of perfection to which each might claim, so that with the single exception of the high efficiency of the marine boiler, upon which doubt was expressed in passing, he believed the various figures might be fully relied upon.

With Mr. Nasmith's observations on the vast importance of an extended use of the Dynamometer, he fully agreed, and should look forward with much interest to the promised paper on this subject.

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INDICATOR DIAGRAMS.

A PAPER

READ BY

MR. JAMES HARTLEY,

(Member of the Association,)

ON 26TH MARCH, 1887,

AT THE GRAND HOTEL, MANCHESTER,

Mr. THOMAS ASHBURY, C.E., Past President,

IN THE CHAIR.

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INDICATOR DIAGRAMS.

As requested by you last year, I now give a paper containing the question of the use of the Indicator, it being a subject that does not receive that attention from users of steam power which its importance demands.

A great many owners of steam engines appear not to know or care anything of the condition of their engine or engines, provided they keep turning round, whilst others, who devote some little attention to the subject and use the Indicator, fail to see the importance of the indicating being carried out as accurately and carefully as is possible, so as to obtain reliable diagrams. They are satisfied, if it is seen by the diagrams, that the valves appear to open and close at about the proper time, and do not care to enter into the equally important subject, as to whether or not, any internal leakage is taking place; whether the steam is being used economically, or applied as it ought to be, which can only be ascertained by a careful comparison with the hyperbolic curve of the curve of expansion on the diagram, for it is well known that without the application of that curve, we are utterly unable to read the diagrams correctly.

As I pointed out in the last paper I had the honour to read before you, so much fraudulent indicating is carried on, either by incompetent men, or to hide defects in construction or working, that reliance cannot be placed on every diagram that is taken from the cylinder of an engine.

That such is the case will be easily seen from the fact, that no person who possesses sufficient knowledge of the Indicator, etc., will undertake to deal with, or give advice on indicator diagrams, unless taken by themselves, or by a person of proved reliability in these matters. Thus it will be seen that before any extensive alterations are made by firms having an *employé* of their own, whose business it is to indicate their engines in the ordinary way, it is well to call in the aid of a third and independent party, competent to assure them that they are working on a safe and sure foundation and prevent them spending money, only to find out when it has been spent, that their engines are no better than they were before. This has

been done scores of times by owners of steam engines. It is also important that firms should be able to know from an independent source whether or not their engineers or engine attendants are doing their respective duties satisfactorily.

I shall endeavour to show you to-night, by the aid of the Oxy-hydrogen light, a series of Indicator Diagrams, photographed from figures carefully traced from the original diagrams, most of which have been taken by myself ; the others have been taken by reliable parties, from almost all types of engines and under various conditions.

The diagrams are all numbered consecutively and will be shown in their proper order, and should any member or visitor wish to make any remarks or desire any further information with respect to any diagram or diagrams, I shall feel obliged if they will carefully note the numbers of such diagrams. This will prevent confusion.

The first diagrams that will be shown, consist of two sets, taken by myself a few years ago from the cylinder of a single non-condensing engine, with automatic expansion gear, controlled by the governor, consisting of a revolving cam working an equilibrium valve, which acted as the expansion valve.

Those marked No. 1, being taken from the engine as it was then working.

The owner of this engine knew little or nothing of steam engines, and was considering whether or not to put in a larger engine as this one would not run at the required speed nor drive the load. He was advised before making any alterations to put indicator taps on the cylinder, and have the engine indicated. After much persuasion he did so, and sent for me to indicate, the result being the diagrams marked No. 1.

It will be noticed that the valve opens and admits a little steam, viz : 18lbs. at one end and 19lbs. at the other end, the pressure then quickly falls and then commences to rise again, until at the time when steam is cut off by the slide valve, the pressure has risen to 28lbs. at one end and 29lbs. at the other end, the pressure in the cylinder gradually rising during the time the piston is at its highest velocity, instead of falling, so as to allow the piston to come easily to rest at the end of its stroke.

It will be seen also, that there is practically no compression in

the cylinder, and that the engine was in a very dangerous state, causing excessive strains on the crank pin, etc., and using steam wastefully.

These diagrams show the importance of periodical indication, especially at works where they cannot afford to keep a competent man, or to purchase an indicator, their engine or engines being small. How long this engine had been in this state the owner had no idea.

Acting upon advice given, the owner discarded this very questionable expansion gear, converted the expansion valve into an ordinary throttle valve and connected it to the governor, lap having been added to the steam edges of the slide valve, with the result, that when the valve had been properly set, diagrams marked No. 2 were taken, and the engine then ran at its required speed of 80 revolutions per minute and drove the load, whilst before it would only run 60 revolutions and not drive the full load.

During the first month after the alterations were made, 20 tons of coal were saved. The saving could have been considerably increased if a smaller cylinder had been applied, as this one was too large, it being found that an initial pressure of 38·5lbs. at one end and 39·5lbs. at the other end, was sufficient to drive all the load comfortably, whilst 80lbs. was carried in the boilers. Could this boiler pressure have been utilised the saving would have been increased, and instead of the owner requiring, as he at first thought, a larger engine, a smaller one, when in proper working order, would have driven his load much more cheaply, without excessive stress or risk of breakdowns.

No. 3, was taken from a single non-condensing colliery pumping engine, with a single locomotive slide valve, and, as will be seen, the steam is admitted during the whole stroke, the initial pressure being only 21lbs. and the terminal pressure 14·5lbs. above atmosphere, or a difference only of 7lbs. between the initial and terminal pressures, the boiler pressure being at the time of indicating 38lbs.

This is a very wasteful manner of using steam and admits of considerable improvement, and taking into consideration that this engine had been working night and day for a very many years, the waste of money must have been considerable. After lap had been added to the steam edges of the slide valve,

the diagram marked No. 4, was taken from the same end of the cylinder as No. 3. That an improvement had been effected will be plainly seen, and was very soon found out by the stoker, whose duty it was to raise steam for this engine.

On diagram No. 4, the initial pressure is 34lbs., steam being cut off at about half stroke, expanding during the other half, until when the exhaust valve opens, there is only 4·5lbs. of steam in the cylinder, or a difference of 29·5lbs. between the initial and terminal pressures, the engine driving in each case the same load and running at the same speed.

No. 5, is a set of diagrams taken from a single non-condensing engine with a single slide valve, and shows that steam is admitted during the whole stroke. The reason for showing these diagrams is to point out a defect very common in some engines and that is, that the exhaust takes place very late, and when it does commence it opens so slowly that almost half the return stroke is made before it is wide open, and, had it not been that the speed of this engine was *very slow*, a considerable amount of back pressure would have been the result during the whole stroke. It would not be too much to say that if the valve of this engine was lapped to cut off at half stroke, the load would be better driven with the expenditure of less than half the steam now used, as the clearance spaces—which are considerable in this engine, and are emptied at each stroke—would be compressed full of steam at every stroke, and saved, in addition to half a cylinder full, by cutting off as before mentioned; yet this engine has been working in this state for several years, notwithstanding that these defects have been pointed out to the owner over and over again.

No. 6, was taken from a non-condensing horizontal engine with Corliss valves, and shows that the valves had got very much deranged, so much so, that steam was late in admission and in cutting off, and that there was no compression whatever in the cylinder at the end of the stroke; also, the difference between the initial pressure in the cylinder and the pressure in the boiler was 27lbs., a very bad result indeed for a Corliss engine; thanks to the indicator, this was soon found out and put right.

No. 7 is the diagram taken after valves had been adjusted. On this diagram it will be seen that the steam is admitted at the proper time, cut off as early as possible to drive the load,

whilst a satisfactory amount of compression is found at the end of the stroke, and the difference between the initial pressure in the cylinder and the pressure in the boiler is only 8·5lbs., an improvement on the previous diagram.

Nos. 8 and 8A, are a complete set of diagrams taken from a compound condensing beam engine of the Woolf type, with an ordinary locomotive slide to each cylinder only. The steam is admitted into the H.P. cylinder during the whole of the stroke, and is almost the same pressure at the end as it is at the commencement, the exhaust being also very bad.

The initial pressure at the top end is 52lbs. whilst at the bottom it is 49lbs., there being no compression in the cylinder at the end of the stroke, this cannot be considered a very good way to apply steam in an engine. The steam is exhausted directly out of the H.P. cylinder into the L.P. cylinder, the pistons beating simultaneously, with a result as seen by looking at the L.P. diagrams, which show more steam on the top side of the piston than at the bottom side, the initial pressures being 13lbs. and 6lbs. respectively above atmosphere; the vacuum also is very bad, being only 4lbs. at the commencement and 11lbs. at the termination of the stroke, there being no compression in this cylinder either.

I need scarcely say that steam was being used very extravagantly in this engine, and taking into account that the coal used to raise the steam for this engine cost twenty shillings per ton, and that the engine had been in this state a very many years, the waste must have been very great. It was not allowed to remain long in this condition after these diagrams were taken, as the valves were overhauled, and lap added to the steam edges, the engine then producing diagrams Nos. 9 and 9A. These compared with the previous ones, show a marked improvement in every respect; the initial pressure is 79lbs. at one end and 78lbs. at the other end, and the steam is nicely compressed at each end of the stroke. In the L.P. cylinder an improvement has also been effected, there being a vacuum of 10·5lbs. at the commencement and 12lbs. at the termination of the stroke, the nett result of this alteration being a saving of 7 tons of coal per week at 20 shillings per ton. The most surprising thing about this engine is that a firm of engineers had been called in some

years previous to this improvement being made, and though they had put lap on the valves, did not succeed in making the engine run, and it had to be taken off again. I was informed by the same firm that they had no belief in the expansion of steam in either or any cylinder of a Woolf engine, but when shown the diagrams (from which these before you have been traced) and told the result, they were forced to admit that there was something in it after all. There is at present a gentleman in this room who assisted the reader to make the alteration to this engine, and who can vouch for the accuracy of my statement.

Nos. 10 and 10A, are a set of diagrams taken from a compound condensing direct acting pumping engine, used for pumping sewage, at the sewage works belonging to the Corporation of a very large borough, and are a sample of the manner in which engines are allowed to work at the ratepayers' expense. The worst feature about them is that they are from a comparatively new engine, and one that is, or at least was, considered perfection itself for the work it had to do. I will pass them by without further remark, except by saying that a more unsatisfactory method of applying steam for pumping, it would be hard to find, and, I am sure, the members of the Corporation owning this engine, would save the ratepayers' money either by discarding or in some way improving it, in order that it may do its work efficiently and economically.

No. 11 is a set of diagrams from one of a pair of condensing engines at a very large engineering works, where it would have been supposed by any one acquainted with the works, that a better state of things existed than is shown by these diagrams. It will be seen that there is 19lbs. at one end and 15·5lbs. at the other end of the stroke above the atmospheric line when the exhaust commences, the vacuum being very bad, there being no compression at the ends of the stroke. To work a condensing engine in the state that this one is in, is a very foolish and an expensive way of using steam.

No. 12 is from a non-condensing engine driving a small flour mill, and is a good specimen of wire drawing through the throttle valve, owing to the engine being too large for its load. The owner was advised to put in a smaller cylinder and by this alteration a clear saving of 20 per cent. would have been the result, but on

calling in an engineering firm (to tender for the alteration) he was informed by their representative, that all he wanted was an automatic expansion gear made by them, and then he would require no new cylinder putting in. A more absurd or fallacious statement was never made, as with a boiler pressure of 70lbs. above atmosphere only 35·5lbs. was obtained in the cylinder at the commencement of the stroke, whilst at the end of the stroke when the exhaust opens, there is only 2·5lbs. pressure. Had an automatic expansion gear been applied to this engine what would have been the result? A higher initial pressure in the cylinder would have been obtained and the steam expanded below the atmospheric line before the piston had made half of its stroke, a very undesirable manner of working a non-condensing engine. Happily the owner of the engine refused to be gulled by this firm of engineers and would have none of their expansion gear on that cylinder; a very wise conclusion for him to come to, as he would very soon have found out had he adopted their suggestion This case proves the advantages to be derived from independent indication of engines.

No. 13 was taken from a non-condensing engine too large for its work, and shows plainly what would have been the result, if the previous engine referred to, had been altered to the recommendation of the engineering firm, as a diagram similar to this one would have resulted.

The boiler pressure in this case was 100lbs. above atmosphere, yet only 30lbs. of this is obtained at the commencement of the stroke, and that is expanded below the atmospheric line before the piston has completed half of its stroke, a very wasteful and foolish application of steam; an engine one-fourth the size would be sufficiently large for the load on this engine. This again shows the advisability of having reliable advice before engines are purchased. The engine in question was a new one.

No. 14 was taken from a small single non-condensing engine at a wire works, and shows the effect on the engine of an unsteady load. The jumping of the governor and closing of the throttle valve cause the full-line diagram to be made, which shows that the compression in the cylinder exceeds the initial pressure, also that the steam is expanded below the atmospheric line, and when the exhaust opens, the atmospheric pressure is admitted, causing

shown in No. 2 when it had the extra load on it, no discrepancy of 40 horse power existing, as was shown in the three previous indications. After indicating, I was shown all the diagrams taken, those by the owner's engine attendant and by the two men from the engineering firm, when to my surprise, I found that each and every one of the diagrams had been taken for one revolution of the engine only, all had therefore committed the same error. By taking diagrams from engines for one revolution only where the load is irregular, an average diagram cannot be obtained, and when these diagrams now before you, which were taken from the engine in question, are looked at, it will be seen how great errors can be committed when taken as before mentioned. Gentlemen, this is further evidence of the importance of careful and independent indications.

Diagrams 20 and 21 require no comment, but clearly show that, a diagram taken from most engines for one revolution only, is not a reliable one.

Nos. 22 and 22A are from the H.P. and L.P. cylinders of a horizontal compound condensing engine, with cranks at right angles, there being no intermediate receiver between the cylinders. On the H.P. diagram the boiler pressure is 25lbs. higher than the initial pressure, and the back pressure in the middle of the stroke, just before the L.P. valve opens, is found to be 25lbs., whilst the initial pressure obtained in the L.P. cylinder is only 13·5lbs., or a loss of 12lbs. between the two cylinders. This is entirely due to the short and crippled passages between the two cylinders.

Nos. 23 and 23A were also taken from the H.P. and L.P. cylinders of a horizontal compound condensing engine with cranks at right angles, but this engine had an intermediate receiver between the cylinders and had also large steam ways. The boiler pressure is almost obtained in the piston of the H.P. cylinder, and the difference between the initial pressure in the L.P. cylinder and the receiver pressure is not more than 1lb. at the commencement of the stroke, showing that when engines are properly designed, the cylinders properly proportioned for the load, and the point of cut-off in the L.P. cylinder carefully adjusted, no matter how large the receiver or passages may be, practically no loss occurs from useless expansion during the time

No. 1, and the valves had springs applied to prevent their dancing, and so much improvement was effected after this was done, that steam could be kept up with four boilers (five having previously been used and very heavily fired) and they also dispensed with the services of one of their stokers.

Nos. 18 and 19, were taken from the H.P. Cylinder of a single Mc.Naught beam compound condensing engine, and show the importance of taking diagrams for more than one revolution of the engine, as called attention to in my last paper. It will not be out of place to relate a circumstance in conection with these diagrams.

I was instructed some time ago to proceed to these works, where this engine along with another single Mc.Naught beam compound condensing engine drive a portion of the load entirely independent of each other. But between the two engines is a line shaft, from which a portion of the load was driven, the shaft being so arranged that by means of two couplings, this portion of the load could be driven by either engine, by simply connecting the shaft to the one and disconnecting it from the other engine. It was found from diagrams taken by the firm's engine attendant, that when this portion of the load was being driven by No. 1 engine that the I.H.P. was 40 more than it ought to have been. The owners not being satisfied with their own diagrams a firm of engineers were called in, who also indicated the engines, calculated the diagrams, obtaining a similar result to what the owners had obtained. Another man was sent by this firm of engineers who also indicated the engines, and when the diagrams taken by him had been calculated, practically the same result as the other was obtained, yet not one of them could give any reason or point out any cause for this 40 horse power that was shown.

As a last resort the firm wrote to the Manchester Steam Users' Association to send an inspector to indicate their engines and report upon them with reference to the matter, and I was sent. I indicated both the engines, with and without this extra load, and also took friction diagrams, and allowed the pencil of the indicator to be in contact with the paper, as is our custom, for 10 or more revolutions, according to circumstances, and when the diagrams were carefully calculated, there was practically no difference in the power of No. 1 engine with this extra load on than was

100 yards, yet the difference between the initial pressure in the cylinder and the pressure in the boilers, is scarcely ever more than 1lb., and many times exactly the boiler pressure has been obtained in the H.P. cylinder; these pipes running for almost the whole distance in the open air, but they are of course very well clothed. I do not posess any diagrams from the engine in question or I would have shown a set, although I have indicated them on several occasions.

No. 31 was taken from a single non-condensing Corliss engine, and the difference between the initial pressure in the cylinder and the pressure in the boilers in this case is only 2lbs. This engine must have large steam ways, as the back pressure line of each diagram, is on the atmospheric line, and when it is known that the engine made 50 revolutions per minute, and had a stroke of 5ft., it will be admitted that a splendid result is obtained from it, in fact, it would be difficult to say, in what way these diagrams could be improved. They may be considered perfect diagrams of their class.

No. 32 was taken from one of a pair of single condensing Corliss engines, and may be considered very good. The boiler pressure is almost obtained on the piston, and with the exception, that there is not sufficient compression in the cylinder at the end of the stroke, they may be considered almost perfect diagrams. I may be allowed to state here, that one of the greatest defects often met with in modern engines—and especially in Corliss engines by some makers—is the insufficient compression found in them. Now, gentlemen, this is a very important point to be attended to, not only in point of economy in the consumption of steam, but also as a preventive of excessive strains on the crank pins, and excessive wear and tear in all engines, but more particularly in high speed engines, and merits more attention from engineers than it now receives.

Nos. 33 and 33A were taken from one of a pair of horizontal compound condensing tandem engines, with cylinders 21in. and 38in. in diameter and 6ft. stroke, making 40 revolutions per minute, pressure in boilers being 70lbs. above atmosphere. These diagrams show that the engines are nicely loaded. The H.P. constant = 5·03 and the L.P. 16·5, the I.H.P. of H.P. is 228·4 of L.P. 178·2, or a total of 406·6 I.H.P. for the two cylinders.

$$\frac{\text{Total I.H.P. } 406{\cdot}6}{\text{L.P. constant } 16{\cdot}5} = 24{\cdot}6\text{lbs. the equivalent mean}$$

pressure upon L.P. piston, if it had been a single engine. The maximum total stress on piston rods is, H.P. 10·8 tons, L.P. 9·1 tons. The apparent range of temperature in each cylinder is—

H.P. from 318° to 218° = 100°
L.P. from 231° to 130° = 101°

or a difference of only 1° Fahr. Total number of expansions between 8 and 9. Gross coal consumption 2·35lbs. per I.H.P. per hour, of slack. The H.P. cylinder has automatic expansion gear, the L.P. flat slides only. This may be considered a very good example of a compound condensing engine for cotton mill purposes, in fact, with same boiler pressure, etc., it would be difficult to beat, all other things being equal. The cylinders are not jacketted.

Nos. 34 and 35 were taken from two single non-condensing Corliss engines, and show how easily it is even for Corliss valves to become deranged unless the engines are periodically indicated in order to ascertain their condition, there being no compression in the cylinders.

Nos. 36 and 36A are two sets of diagrams taken from the H.P. cylinder of a compound condensing Corliss engine, No. 36 showing how the valves can become deranged in the short time that intervenes between the visits of the engine inspector, and No. 36A what the diagrams should have been, and what they were after the inspector had adjusted the valves for the firm, and is further evidence of the importance of periodically indicating steam engines.

No. 37 was taken from the H.P. cylinder of a compound condensing engine, with the cranks placed almost opposite each other, being thus placed in order to overcome the rise in the back pressure line in the middle of the stroke of the H.P. cylinder, due to the cranks being at right angles and there being no receiver between the cylinders. I think it will be admitted that not much improvement was effected, as the steam is badly distributed, and the turning was so bad that they altered the cranks back again and placed them at right angles one to the other, in which position there is no doubt, the most uniform and regular turning is obtained.

No. 38 was taken from a single old beam condensing engine, and shows that the steam is late in admission to the cylinder and that there is no compression at the end of the stroke; this is working at a great disadvantage and could be improved considerably, and about 25 per cent. of the steam now used saved, even with the present boiler pressure.

No. 39 was taken from a single horizontal condensing engine, and shows the exhaust to be late in both opening and closing, and that there is practically no compression at the end of the stroke.

No. 40 was taken from each end of a new high-speed inverted vertical Corliss condensing engine, driving a cotton mill, in which the valves are set so as to give more steam on the underside of the piston than on the top side, in order to balance the weight of the moving parts; so I was informed.

No. 41 is similar to No. 40, except that the steam is late in admission at the underside of the piston, and was taken from a smaller but similar engine, at an engineering works. If this type of engine is to become universally adopted at our cotton mills, a thing that some people would have us believe, a better method of balancing will have to be found, also better results obtained than are being obtained from the few that are now at work.

No 42 was taken from a new horizontal condensing engine, put down to drive a weaving shed, and is a specimen of the class of engines turned out by some engineering firms. This had a cut-off valve on the back of the main slide valve, but it is evident from the diagrams, that it was not set to cut off steam at an economical rate, in fact, we may assume it did not act at all, the main slide—as is generally the case in this class of engines—is made without any lap. This is evident from the harsh steaming and late opening and closing of exhaust, there being no compression in the cylinder at the end of the stroke, the effect of which can be plainly heard by anyone who is acquainted with the working of engines, immediately they enter the engine-house, by the sharp knock that takes place in this engine when the centres are being crossed, all the bearings being in first-rate working condition, no play being in any of them. The load on this engine was only light, but it ought to be driven by one-fourth the quantity of steam now used, and would be if the valves had been properly constructed

and set. Remember gentlemen, this was a new engine made by a firm that advertises considerably, and we ought to expect better engines from them.

Nos. 43 and 43A are all from one of the H.P. cylinders of a pair of Mc.Naught beam compound condensing engines, at a large cotton mill. No. 43A were taken from a cylinder 38¼ins. diameter, with an ordinary single lapped locomotive slide, the boiler pressure being 55lbs. above atmosphere, and not much fault can be found with them, when everything is taken into account. It is only when such diagrams are compared with others similar to No. 43 that we see the advantages to be derived from high pressure steam properly expanded. No. 43 was taken from the same engine as No. 43A after smaller high pressure cylinders, with Corliss valves and automatic expansion gear had been added, along with new boilers, and the pressure raised to 100lbs. above atmosphere. I am very well acquainted with several firms who have boilers that work regularly at a pressure of 80lbs., their engines being only single condensing. Out of the 80lbs. boiler pressure it is only possible for them to obtain 30 to 35lbs. as the initial pressure in the cylinders, owing to wire drawing through the throttle valve, from too large cylinder capacity, they being perfectly satisfied with this result, and refusing to compound their engines and reduce their cylinder capacity, and put automatic expansion gear on their cylinders so as to utilise the boiler pressure, although it can be clearly shown to them, that a saving of at least 25 per cent. would be the result of their so doing. Now gentlemen, I think, if the parties in question, only knew the saving effected in the engines from which Nos. 43 and 43A diagrams were taken, they would surely not hesitate any longer. I am informed from a reliable source, and am also at liberty to tell you, that the nett result of the change in these engines, as before mentioned, effected a saving of 25 tons of coal per week and the services of one stoker dispensed with. When such facts as these can be attested, we should naturally think that those who have doubts as to the utility of making such changes would doubt no more.

No. 44 was taken from a single condensing rotary pumping engine at a colliery, the steam is here shown to be late in admission to the cylinder.

No. 44A was taken from the same cylinder after the valve had been adjusted, and is a decided improvement on the previous one. This being a good sized engine, the improvement would not be long in making itself felt in the stokehole. A great many colliery proprietors are under the impression that there is no necessity to indicate colliery engines, but some experience that the Manchester Steam Users' Association have had of late in this matter, has convinced us, of the importance of even indicating colliery engines. This question will be again referred to, and some more diagrams, from both colliery winding and pumping engines, shown further on.

No. 45 was taken from the H.P. cylinder of one of a pair of Mc.Naught beams, and shows the valves to be very badly deranged, and what is most surprising about them is, that they had been left in this condition by one of the makers' workmen, who had been overhauling and resetting them the week end previous to these diagrams being taken.

No. 45A was taken from the same cylinder as No. 45, after the valves had been adjusted. That an improvement had been effected and the working of the engines considerably improved, no one will deny Had these engines not been enrolled for periodical indication, there is no saying how long they would have worked as found by the inspector when diagrams Nos. 45 were taken, since the firm did not possess an indicator of their own, and if they had possessed one, the probability is, that they would not have applied it, as they took it for granted that after a firm of engineers had overhauled their valves, they would certainly leave them in good working order and properly set. Evidently, this is not always the case, as seen from this example. I could give you many more similar instances that have occurred, some so recently as this year, so we may come to the conclusion, that it is advisable to indicate even after the valves have been overhauled by many engineering firms.

Nos. 46, 47, and 48 were each taken from different engines, and are further examples of a common defect met with in almost all engines with cut-off valves on the back of the main slide valve, viz., that the main slides are made entirely without lap on the steam edges, and in some instances do not even cover the ports. The only point some makers look to is the cutting off of

the steam, entirely neglecting the exhaust, which is equally important. The main slides of all engines with back slide cut-off valves on, should always be lapped to cut off at about ⅞ths. of the stroke, in order to ensure a timely and clear opening and closing of the exhaust.

No. 49 is a set of diagrams from the H.P. cylinder of a compound condensing tandem Corliss engine, one of them showing a re-opening of the steam valve due to excessive compression in the dash pot, causing a rebounding action of the air piston and connections to the valve. The dotted line shows the expansion curve as it would be if the valve were in proper working order.

No. 50 was taken from the H.P. cylinder of a compound tandem engine, with Meyers' expansion slides at the back of the main slide, controlled by the governor, and shows a reopening, or a second admission of steam, due to a piece of lap having broken off of the valve in working, and this again shows the importance of indicating.

Diagrams 51 and 51A are from a compound condensing beam engine of the Woolf type, of which nothing can be said in its favour either for efficiency or economy in working.

Nos. 52 and 52A were taken from the same engine after the Woolf cylinders had been removed and the engine converted into a Mc.Naught beam, and show the superiority of beam engines of the Mc.Naught type, over the old and antiquated Woolf.

No. 53 was taken from the H.P. cylinder of another Woolf compound condensing beam engine, previous to its being converted into a Mc.Naught beam by putting in new cylinders, &c.

No. 54 was taken from the H.P. cylinder after it had been Mc.Naughted, and the improvement in the diagrams is well defined; there was also an improvement in the coal bills.

No. 55 was taken from both cylinders of a tandem compound condensing Corliss engine, with the same spring and on the same card. This was a new engine that had been put down to replace a beam engine that was worn out. A glance at the diagrams shows that the cylinder capacity is *very much* too large for the load it has to drive. This is a defect that is often met with, some makers especially, err in this. It is evident in this case, either that the old engine had not been indicated before the new one was designed, in order to ascertain exactly what

load had to be driven, or else a very great mistake was made in the calculations. No excuse could be offered that the engine had been made larger to provide for an increase in the load, as there is no probability of the load ever being increased. The H.P. cylinder alone, if it had been connected to the condenser, would have driven this load cheaper than it was being driven when these diagrams were taken. Need there been any wonder at the owner complaining that he used more coal with the new engine than he did before with his old one.

No. 56 was taken from both cylinders of a compound condensing tandem engine that had been put down to replace an old engine, and is even a worse case than the last. These examples prove conclusively that something more than a rule of thumb method is required in designing steam engines, but I am afraid some makers—judging from the engines turned out by them—adopt this method in designing them. It will be noticed that there is a very great fall in the pressure between the high and the low pressure cylinders, which is the case in all this maker's engines that I ever saw, and it is due to the short and contracted passages the steam has to pass through.

No. 57 was also taken from both cylinders of a compound condensing tandem Corliss engine, with a receiver between the cylinders, and shows that the builders of this engine, have designed it on scientific principles. It will be seen that the fall in pressure between the H.P. and L.P. cylinders is very small indeed, although, as before stated, there was a receiver between the cylinders. I have always argued that the application of a receiver between the H.P. and L.P. cylinders of a tandem engine, in order to have a supply of steam ready to rush into the L.P. cylinder immediately the valve is opened would be an advantage, providing the point of cut-off in the L.P. cylinder be properly adjusted, and this proves that it is so. This engine is far superior in every respect to the two previous specimens, from which diagrams have been shown, yet all three were made by engineering firms who are considered A 1. makers of engines.

No. 58 was taken from a small single condensing engine, and the peculiarity about it is the point at which the exhaust closes. The cause of this was due to the action of a small pulley, over which the cord passed, having worn oval in the hole, and at this

point described an eccentric motion, causing the barrel of the indicator to jump a little.

No. 58A was taken from the same engine after this pulley had been removed and a new one applied, and it will be seen it differs entirely from the previous example.

No. 59 is from the H.P. cylinder of a compound condensing tandem engine, and shows the effect on the diagrams through having the pendulous lever that drives the indicator too short; it also shows that the engine is too large for the load, there being a vacuum of 6 or 7lbs. in the H.P. cylinder.

No. 60 was taken from the H.P. cylinder of a Mc.Naught beam compound condensing engine, and also shows the effect of an incorrect method of driving the indicator.

No. 61 was taken from a single noncondensing Corliss engine, and was referred to in my previous paper, with reference to excessive pressure being applied on the indicator pencil. These are the diagrams taken by the firm's engineer, showing the steam line to be parallel to the atmospheric line.

No. 62 was taken by me from the same engine, just previous to No. 61, and shows very clearly, that unless diagrams are carefully taken they are worthless. On one of these diagrams it will be seen, the steam commences to fall immediately the piston moves, which is not the case in the diagrams No. 61, simply because of the extra pencil pressure given. As I referred fully to this in my last paper no more need be said now.

No. 63 is from the L.P. cylinder of a compound condensing engine, and shows the steam to be admitted so harshly to the piston, that it sets up vibrations in the indicator, which continue until the engine has completed its stroke.

No. 64 was taken from the same cylinder immediately afterwards, but extra pencil pressure was applied, so much so, that the vibrations are not seen, but these cannot be considered correct diagrams.

No. 65 was taken from the L.P. cylinder of a compound condensing engine, and is similar to No. 63.

No. 66 is from the same engine as No. 65, but in this case extra pressure was applied to the pencil, and is similar to No. 64.

No. 67 was taken from one of a pair of colliery winding engines, practically new engines, with link motion reversing gear,

the character of the curve, and aids in its construction and verification, since corresponding portions on either side of it are alike. The hyperbola may be commenced at either end of the expansion curve. Generally, it will be found the more accurate way to commence near the point of release. A point having been selected, divide the length of the diagram up to this point, and including the clearance, into any convenient number of equal parts, the more numerous the better. Multiply the pressure at the point selected, into the number of parts, and the product will be the pressure, according to the law of the gases, at the end of the first of these parts, supposing it to be carried so high; and the pressure at the end of any part is found by dividing the pressure at the end of part one, by the number of parts up to such point.

Diagram No. 73, from a Corliss engine, has been divided to illustrate this method. At the end of the thirteenth division the pressure is 9lbs. absolute, so at the end of the first division it would be 117lbs., at the end of the second one 58·5lbs., at the end of the fourth 29·25lbs., and so on. The method is extremely simple, only care must be taken that ordinates and not diagonal lines are measured. Above the axis the point of intersection of the ordinates with the curve become separated too far for accuracy. It is better to substitute the abscisses as shown in this diagram. These are numbered to correspond with the ordinates, and then the lengths are transferred from the latter. The curve passing through these points is the hyperbolic curve. On the application of the hyperbola to this diagram it is shown that condensation continues after the steam has been cut off, and passing slowly into re-evaporation. The commencement and progress of the latter action is seen in the expansion curve ceasing to depart from, and then approaching, and finally crossing the hyperbola.

No. 74 illustrates another method—and the one that is most used—of laying down the hyperbolic curve, and it is laid down as follows:—Firstly, draw the line AA to touch the top of the steam line in the diagram; secondly, draw the pure vacuum line; thirdly, at the admission end of the diagram, draw the line representing the clearance, giving the point B on the pure vacuum line. Now draw a line from B to the top of the ordinate at which the point C is taken—in this example it is taken at 7B, but it may be taken at any point at which we are sure the admis-

sion of steam has ceased and the port closed—from C draw a line parallel to the atmospheric line until it intersects the line 7B, then draw a vertical line D D through this point 7. Join the tops of the ordinates 3, 4, 5, 6, 8, 9, 10, to B, the lines intersecting D D in 3'', 4'', 5'', 6'', 8'', 9'', 10'', then draw lines parallel to the atmospheric line through these intersections to the corresponding ordinates, giving points on the curve, the intersection of line D D with A A being the first.

Nos. 75 and 76 are examples of an American method of demonstrating the actual point of cut-off from the steam used, without regard to terminal pressure or lack of distinctness in the cut-off line, and which is done regardless of the amount of clearance in the cylinder, when only the actual point of cut-off is required. This method has been examined by some of the best mathematicians, and has been pronounced correct.

Diagram 75 was taken from a Corliss engine that had been running many years, and it is on this that this method is applied. To explain the demonstration, first draw the line of initial pressure C, then the line of absolute vacuum D, the vertical line B, which in this case represents the clearance of the engine. We have now actually known factors. At some point in the expansion line, in this case at the crossing of the expansion with the line of rest of the instrument, we draw the vertical line A to the absolute vacuum line; this is also a known quantity; it is the actual pressure in the cylinder above the vacuum line, it is, therefore, a known quantity. There is no special reason why we locate it at this particular point in the stroke, only at that point the line is entirely settled in its work. Now from the intersection of A D we draw the the angular line E, which connects the the base of A with the intersection of B C, at the point representing the clearance of the engine, added to the diagrams, and the line of initial pressure. This line is for the purpose of demonstration; now we wish to obtain a parallel line to the one just erected; measure the distance from A to the line just erected on the atmospheric line, in this case the top of the line A intersects with the atmospheric line, lay of this distance A E on the line C, which gives the distance F I, lay off the same distance on the line D which gives us D K, or the distance from A to the new line K F. F is therefore the point at which

the initial pressure of steam should have been cut off to have given the pressure A at that point in the expansion line. It will be seen that the fact and the demonstration do not agree apparently. This is the end of the demonstration practically. Now if we compare results, we find that the lines of the indicator diagrams, as left by the instrument, show a very much shorter cut-off than the line F. But, at the point J the theoretical curve dropped from the line F, joins with the actual line of the instrument, and from the point J the theoretical and the actual curves run on together. After the valve of the engine closes, an amount of steam passed through, under it, into the cylinder, and the amount of steam increased after the cut-off was shown by the indicator to equal the amount shown by the shaded portion of the diagram, between the actual line of the instrument and the theroretical line, dropped from F, continuing to H J, or about twenty per cent. The point F represents the point of cut-off equalling the actual amount of steam put into the cylinder, taking the whole diagram as demonstrated. The steam leaked into the cylinder from the time the cut-off valve was apparently closed, as shown by the indicator up to that point in the stroke represented by J where the leakage stopped, the valve having then become positively closed, and no more steam was admitted. Upon examination of the engine after this diagram was taken a bad leak was discovered in the steam valve, thus proving the conclusion arrived at from this demonstration.

No. 76 is shewn to contrast No. 75 and was taken from an engine exhibited at the Philadelphia Exhibition by Mr. Geo. H. Corliss. In this case we erect first the line of initial pressure, then the pure vacuum line. But the clearance is not known, and in contrast with No. 75 the base line A is made below the atmospheric line, the demonstration is then made precisely as in the former case, with the result that the motion of the valve is a trifle slow as compared to the stroke, and the visible and actual points of cut-off vary slightly, but come together at the point J which in this case is much nearer the commencement of the stroke. The actual and theortical curves then run along almost identically. It will be noticed that there is nothing assumed here, and if the demonstration is carefully made, which any one can do with a pair of triangles, they will get positive

results. F I represents the amount of steam introduced into the cylinder; the convexity at H in this diagram is caused by a slight leak in the valve when it seats itself.

No. 77 is a diagram showing the rotary effort upon the crank pin—inertia of moving parts being neglected—due to the pressure of steam upon the pistons, cranks being at right angles; cylinders 32in. and 56in. × 6ft. stroke, running 40 revolutions per minute; ratios of cylinders 3 to 1, cut-off in each cylinder four-tenths of the stroke, I.H.P. in H.P., 429; in L.P., 481; total I.H.P., 910.

No. 78 is a diagram showing the rotary effort upon the crank pins of the same engine under the same conditions, except that the cranks are placed at opposite centres, and the conclusion which we must arrive at is that the position of cranks which gives the most uniform turning, uniform strains on crank pins, &c., and I may say the most economical results, everything else being equal, is at right angles one to the other, a receiver being placed between the cylinders and due regard paid to the point of cut-off in each cylinder.

No. 79 is a combined diagram taken from a compound non-condensing engine, with cranks at right angles but no receiver being between the cylinders. The space shaded shows the apparent loss between the actual and theoretical diagrams which in this case cannot be considered excessive, the engine exhausting through a feed water heater to the chimney.

No. 80 is also a combined diagram taken from a compound condensing tandem engine. As in the previous example the shaded portion represents the difference between the actual and theoretical diagram; the loss in this engine is considerably more than ought to be, and is simply due to the relative proportion of the cylinders, one to the other being too great. The vacuum is also very poor owing to insufficiency of condensing water supplied to the condenser.

Nos. 81, 82, and 83, are each complete sets of diagrams, kindly sent me by Messrs. Hornsby & Sons, of Grantham, through Mr. Ashbury, and were taken from one of their compound non-condensing under-type engines, with cylinders 8in. and 12¾in. × 1ft. 4in. stroke, making 135 revolutions per minute, the boiler pressure being 140lbs. above atmosphere, and represent diagrams made by this engine during three

positions of the governors which control an automatic expansion gear. No. 81 was taken with the governors down, No. 82 with the governors half up, and No. 83 with the governors up.

Nos. 84, 85, and 86 are each a complete set taken from one of the above named firms non-condensing compound engines, with cylinders 10in. and 17½in × 1ft. 6in. stroke, making 120 revolutions per minute, the boiler pressure being 140lbs. above atmosphere. No. 84 was taken with the governors down, No. 85 with the governors half up, and No. 86 with the governors up.

They may all be considered very good diagrams and show that the cylinders are nicely proportioned, that the steam and exhaust passages are of ample capacity to permit the steam to enter and escape from the cylinder freely, a very important point, especially in high speed engines. I may here remark that a great many of our large engineering firms might take a lesson from some of the makers of this class of engines, both as regards design, proportion, and finish.

Nos. 87, 88, 89, 90, and 91 are diagrams from an Otto gas engine, kindly supplied and taken by Mr. W. H. Booth, of Manchester. No. 87 is the complete diagram and shows the indraft pressure line *a*, the compression line *b*, the line of explosion *c*, and the line of expansion *d*. The line *e* next follows; this is the exhaust line. This completes the explosive cycle of two revolutions. When no gas is drawn in however, the line of compression *b* is not followed by explosion, but by the non-working expansion line *f*. Now between the line *b* and the line *f* there is a space which represents the difference between the power used to compress the charge of air and the work again given out by it expands without explosion. This difference is in favour of the engine. There is also a space between the indraft line *a* and the exhaust line *e*, and this tells against the engine, being a negative diagram.

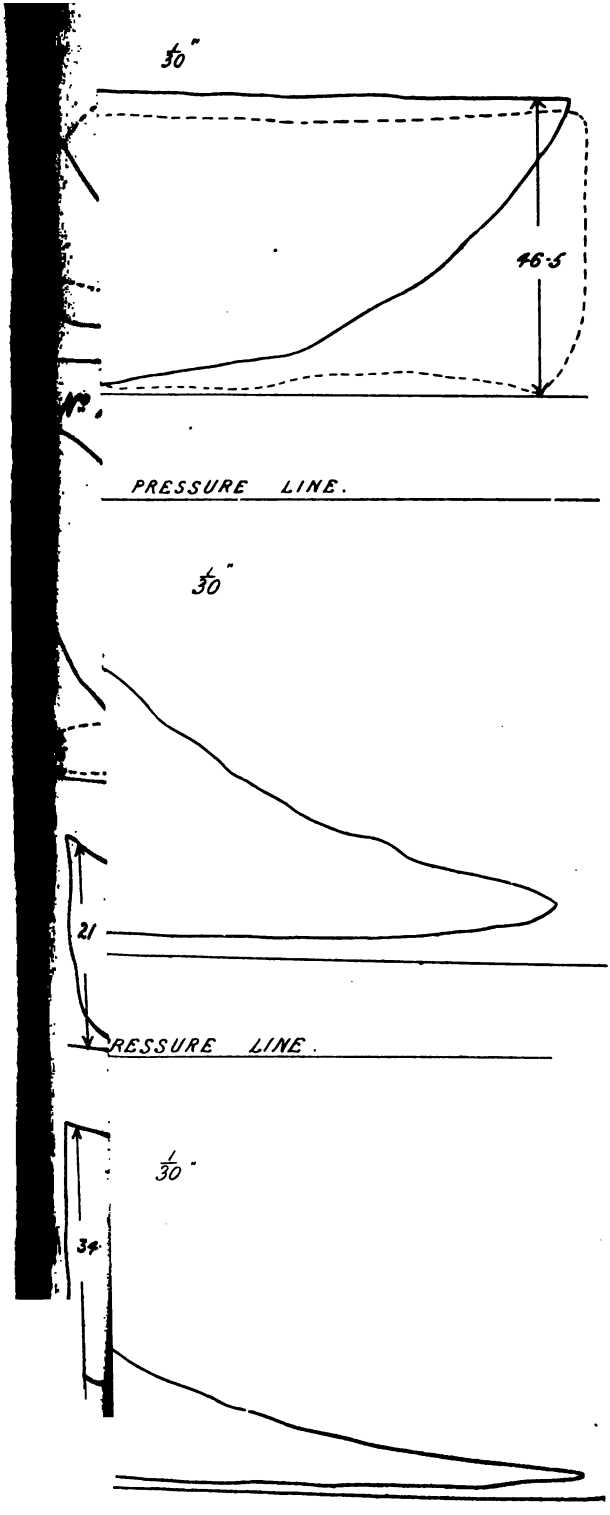
Now, it is customary to look upon diagram No. 88 as the diagram giving the power of a gas engine. It is essential however, to remember that from the power shown by diagram 88, must be added, and deducted the power shown by the smaller diagrams 89 and 90, and to do this it is necessary to know what proportion of the strokes of the engine are working or explosive strokes, and how many are idle, for a gas engine rapidly becomes

less economical, as its load falls away from the maximum. I may say that these gas engine diagrams were taken with a Richard's indicator and with a gasoline patent mixture of high potency, as compared with ordinary coal gas; but diagram No. 90 shows how in a gas engine not properly arranged, late, or imperfect explosions may sometimes occur. It is worth notice too, that more work is given out by the expansion line *f* of the non-explosive cycle than is consumed in compressing it up the line *b*. This at first seems curious, but when we reflect that cold air is drawn in and becomes expanded during the return stroke, we readily perceive that the extra power shown is due to heat abstracted from the cylinder walls. Another notable and interesting point, is seen in the fact, that the exhaust line *e*, which follows the explosive stroke, has an absolutely less pressure than the exhaust line *g*, which follows a non-explosive stroke. Probably this is due to the condensation by the cylinder walls of the steam formed by the explosion, serving to produce a partial vacuum in the cylinder. No. 88 is not therefore a full gas-engine diagram, though probably from it may be measured very closely the actual power of the engine, while the minor diagrams possibly about balance each other.

The gas-engine is an interesting subject to study, by the light thrown on it by the aid of the Indicator, and it may here be stated that gas-engines would be much improved and their working made more economical, if means were taken to ensure a high temperature to the water jacket.

Nos. 92, 93, 94, 95, 96 and 97, are diagrams from probably the first triple expansion engines made, and have been kindly sent me by Daniel Adamson, Esq. Nos. 92, 93 and 94, are complete sets from each cylinder of the right hand engine of a pair, and Nos. 95, 96 and 97 are from the left hand engine of the same pair, with cylinders 16ins., 22ins., and 38ins., × 6ft. stroke, making 33·5 revolutions per minute. The total I.H.P. of the right hand engine being 299·42, and of the left hand engine 322·41, or a total I.H.P. of 621·83.

Nos. 98, 99, 100 and 101, are complete sets from each of the cylinders of the first quadruple expansion engine that was made, have also been kindly sent me by Mr. Adamson, the cylinders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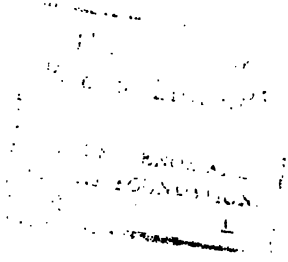

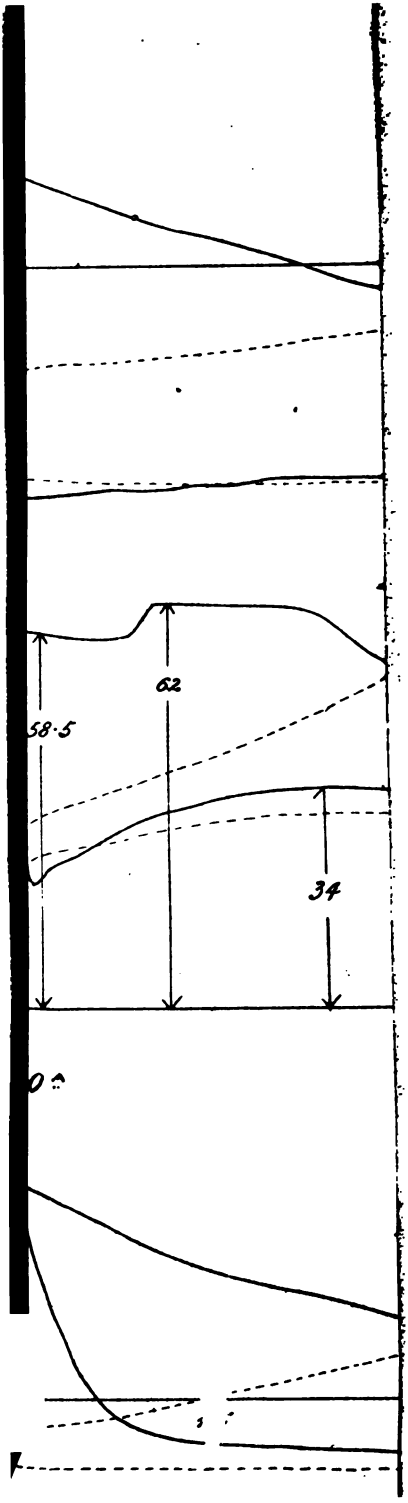
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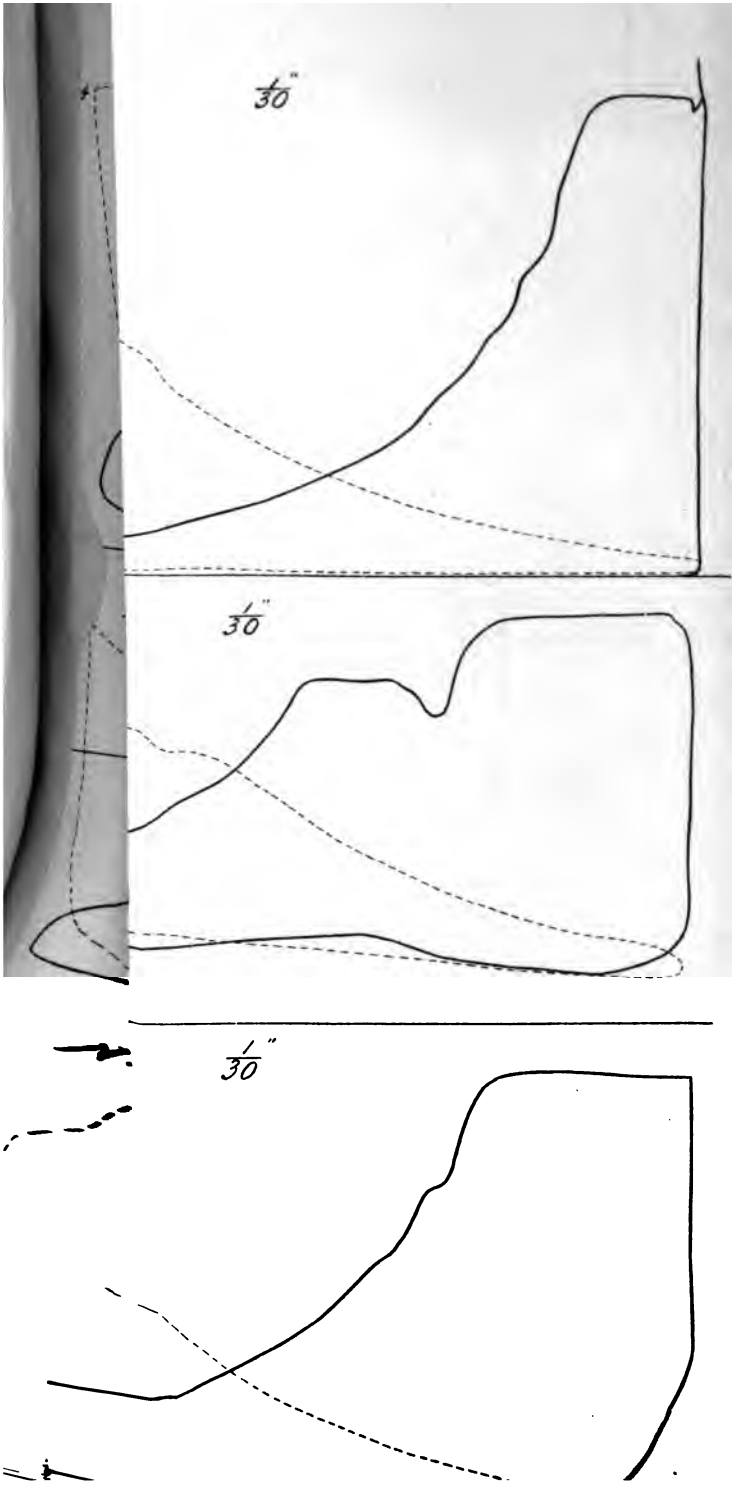
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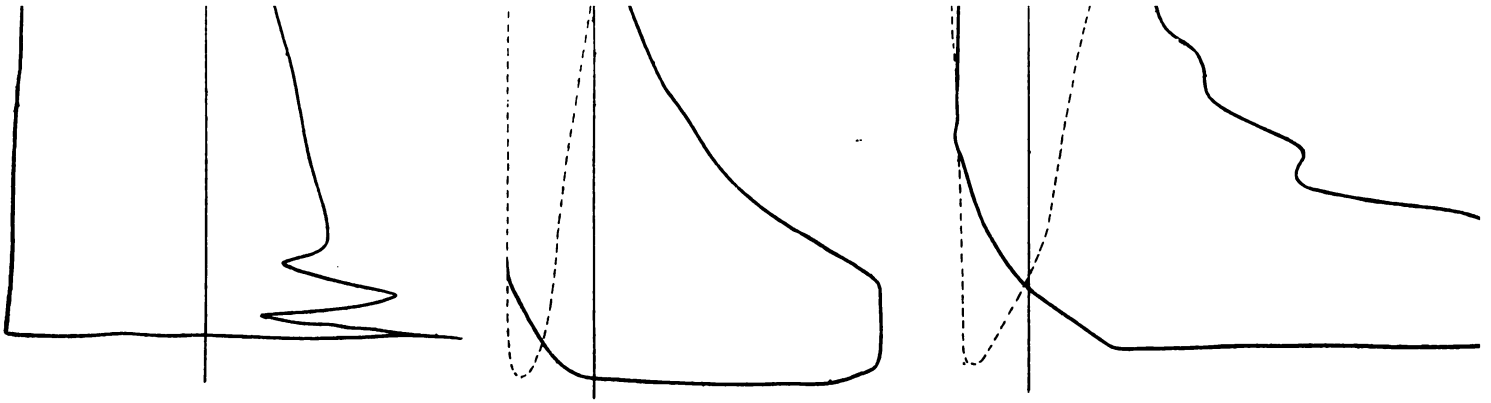

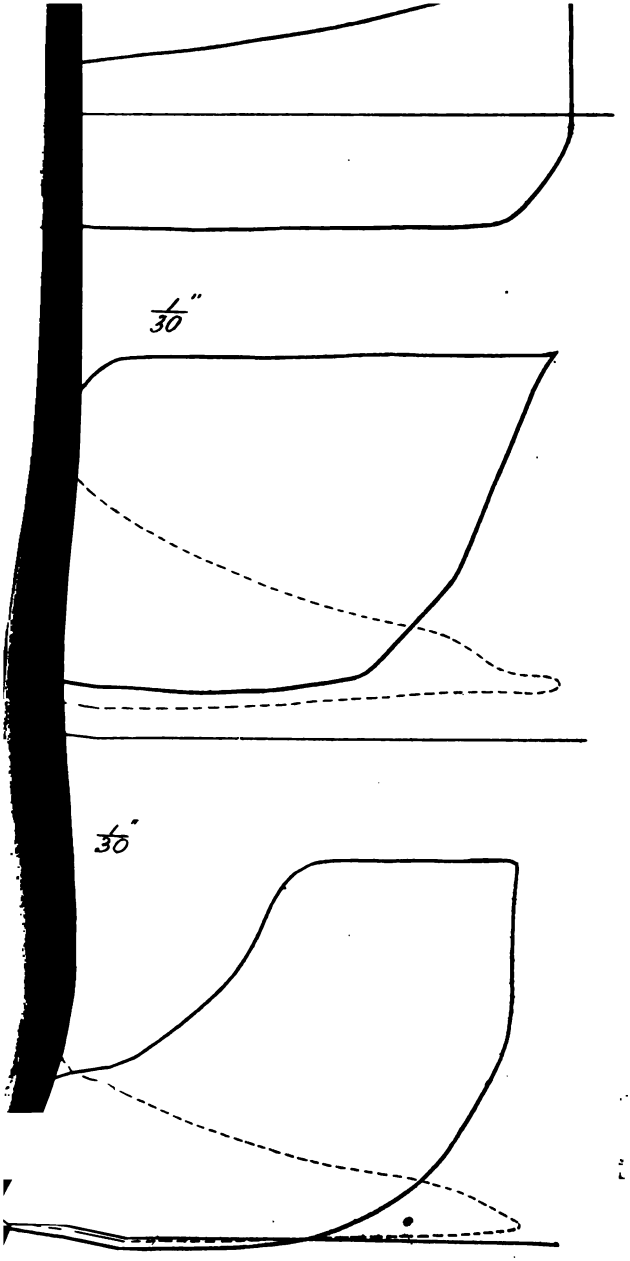
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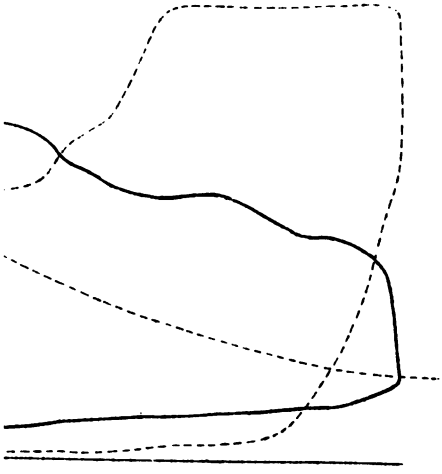

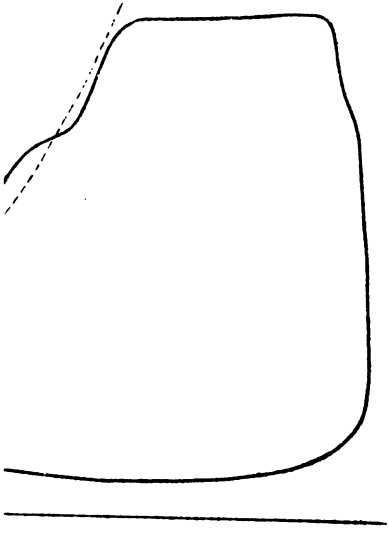

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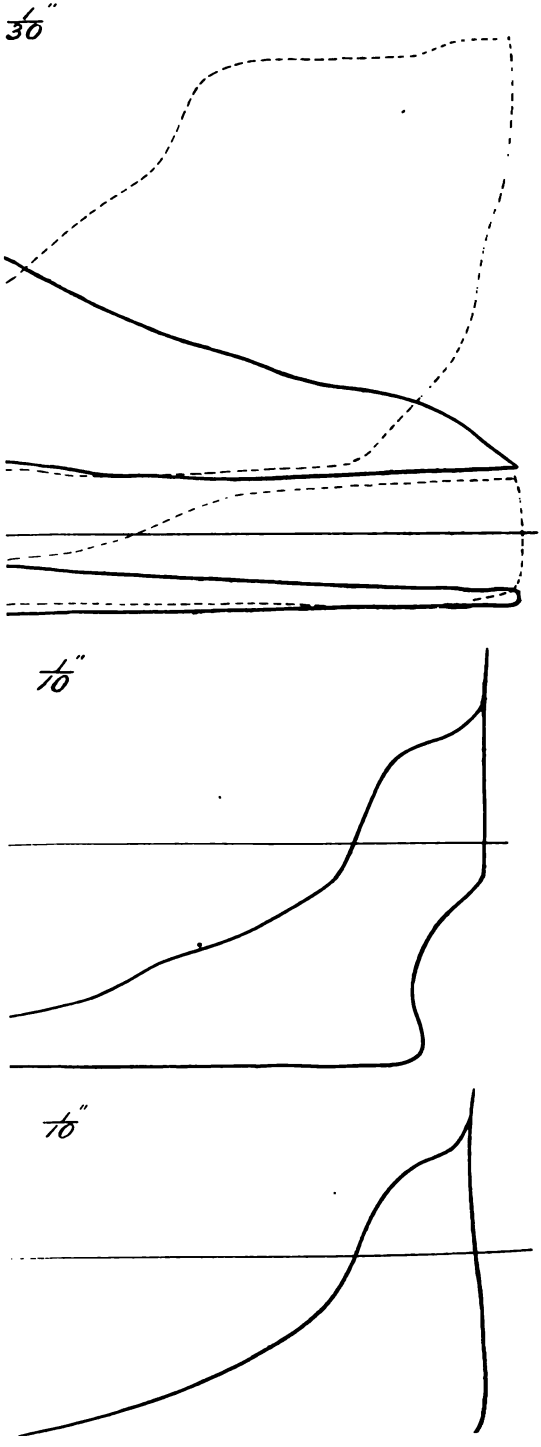
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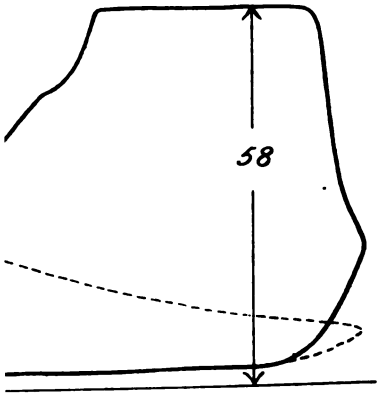
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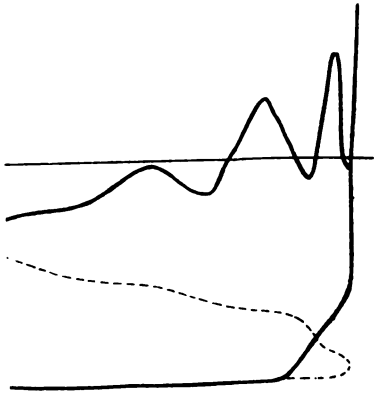

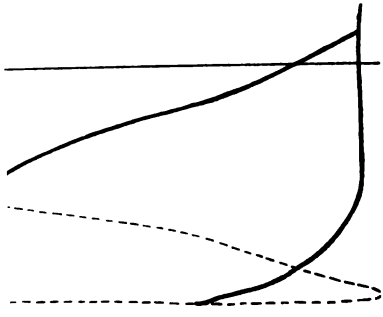

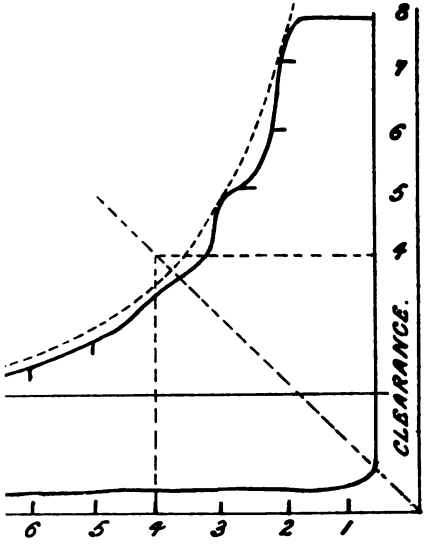
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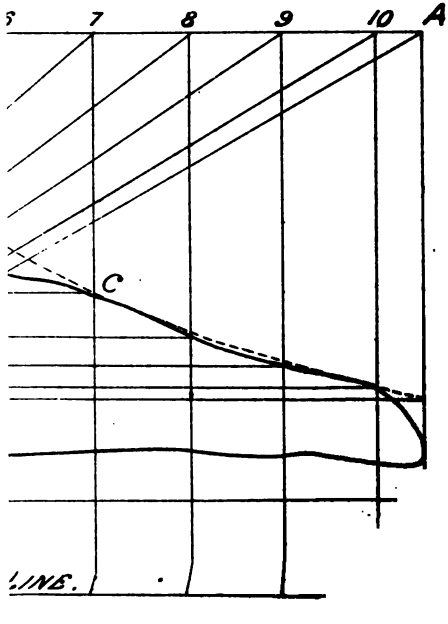
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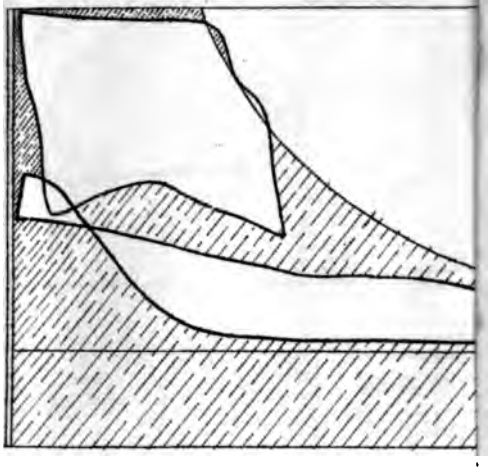

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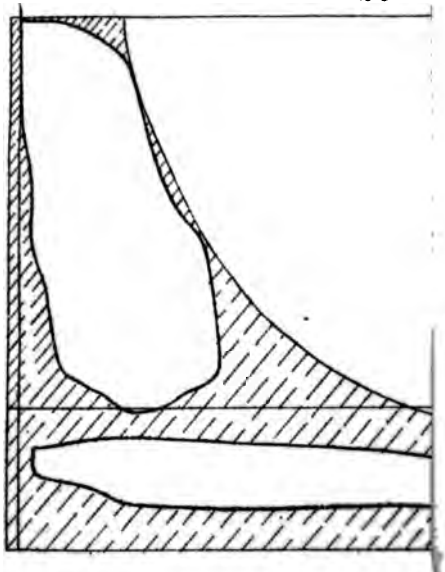

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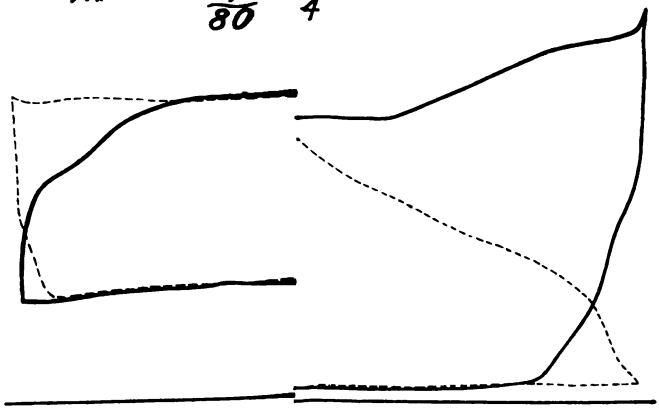

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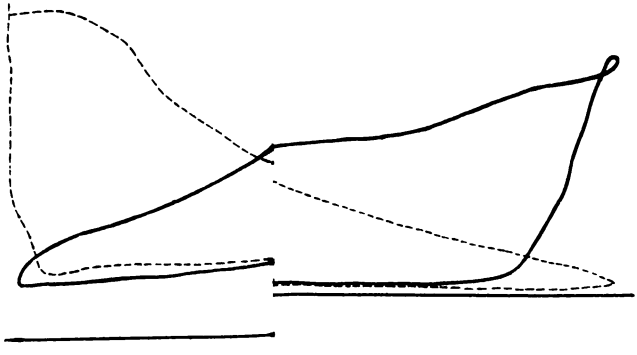

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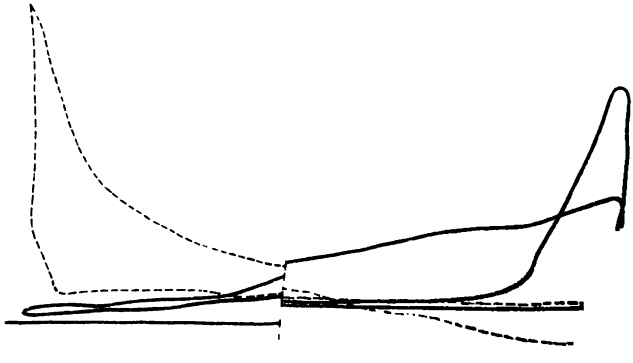

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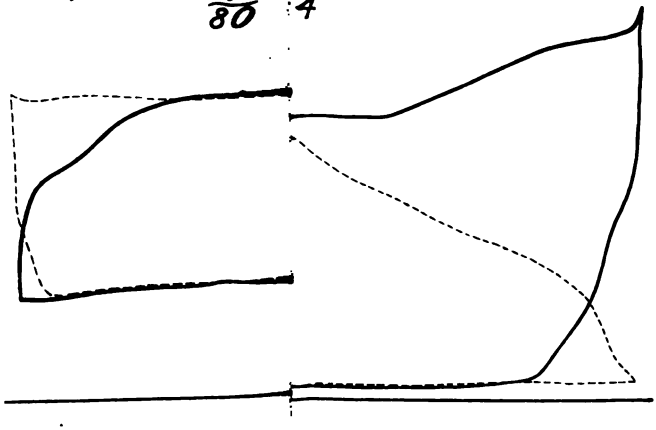

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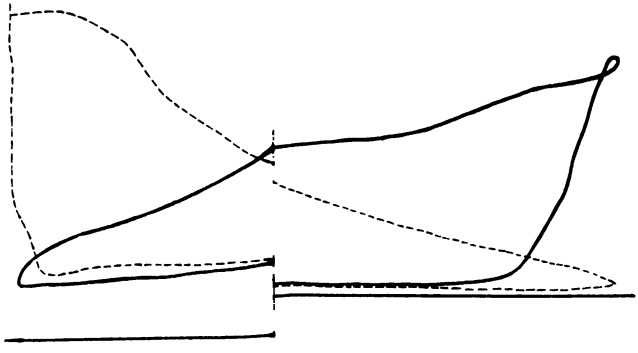

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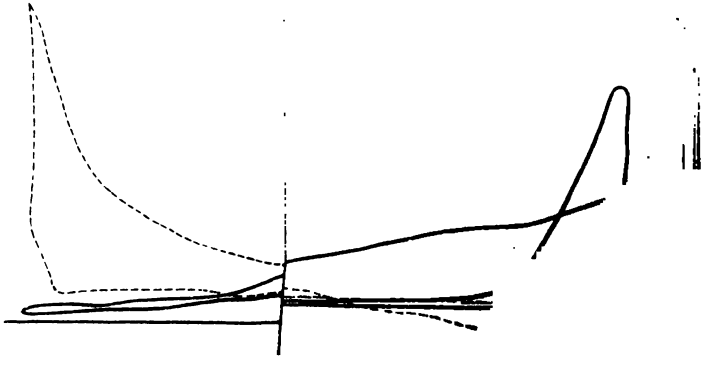

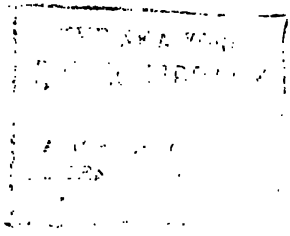

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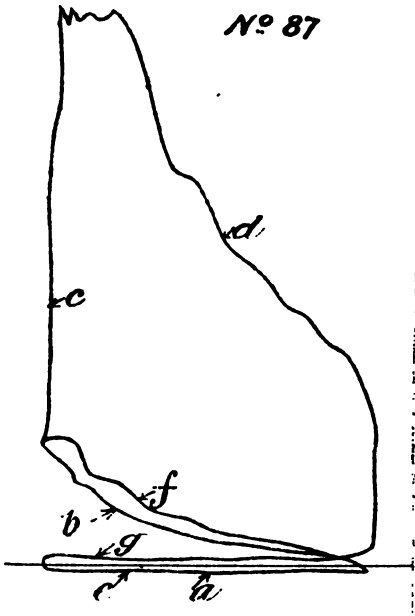

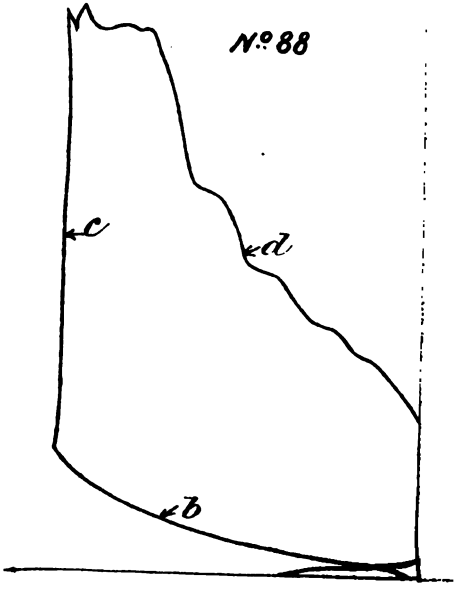

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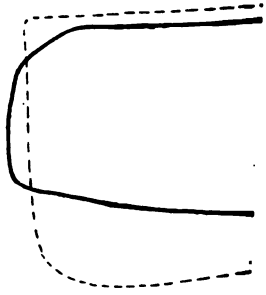

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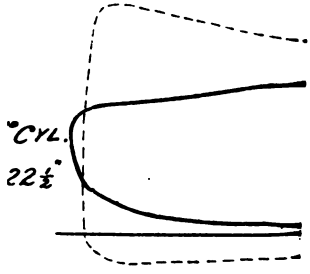

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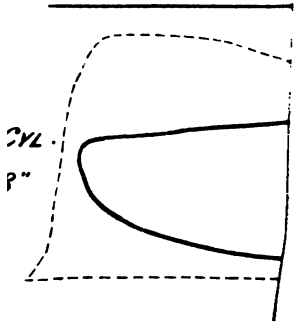

in fact, better than many compound engines. Of this I am well aware, but all compound engines are not made to give economical results—as will have been seen from diagrams shown you to-night—either through blundering or from the want of thorough scientific knowledge in the designing of such engines, but if compound engines are made on the lines just laid down, it will be utterly impossible for single cylinder engines to approach them in anything.

Gentlemen, I appeal to the engine designers and makers of Lancashire, to strive and make their engines in the future scientifically, and to throw away those old rule of thumb methods that they have of late years clung to so tenaciously, and to let us see, that in engine making, they are still in the front ranks, or depend upon it, they will be elbowed out of the way, and must take a second or third position in the trade of the future.

I thank you all for your attendance here this evening, to hear the relation, and to see some of the practical experience I have had among the different engines, which it is the lot of an engine inspector to come across, but I cannot sit down until I have expressed my sincere thanks to my friend, and one of our members, Mr. John M. Frankish, for his kindness in giving his leisure hours to photographing the diagrams shown to you this evening.

I scarcely knew in what manner to show the diagrams until I hit upon this method, and I hope the way they have been put before you will meet with your approval, as I believe this is the first time in which Indicator Diagrams have been shown by the aid of a lantern.

Votes of thanks having been passed to Mr. Hartley for his valuable contribution to the records of the Association, to Mr. John M. Frankish who had kindly photographed all the diagrams shown, and to Mr. Burchem for assistance rendered during the reading of the paper, the proceedings terminated.

On the suggestion of the Chairman, the discussion was adjourned until the 23rd April. In the meantime the paper to be printed and issued to the members.

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VISIT TO THE ROYAL JUBILEE EXHIBITION, MANCHESTER,

16th July, 1887.

ADDRESS BY THE PRESIDENT,

ALDERMAN W. H. BAILEY.

MANCHESTER:
HERALD & WALKER, PRINTERS, BACK POOL FOLD, OFF CHAPEL WALKS.
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215, Warde Street, Hulme.

VISIT TO THE

Royal Jubilee Exhibition, Manchester.

The Members of the Association visited the Jubilee Exhibition on Saturday, 16th July, 1887, and were received in "Ancoats Old Hall" by the President and Mrs. Bailey, who afterwards entertained the company in the Palm House Dining-room, about 150 being present.

The President in welcoming them said:—

The members of this Association may, I think, exchange hearty congratulations on the grand success of this Exhibition, erected to celebrate the Jubilee year of Her Majesty's reign.

It is matter for congratulation, because, in the engineering section especially, nearly every member of the Manchester Association of Engineers is either directly or indirectly represented.

THE VICTORIAN TRIUMPHS.

Ready writers have described the great intellectual triumphs of our Queen's long reign, and these will readily occur to our minds. Progress has been made in the arts of peace, in the refinements of life, in the development of the knowledge of causes, in fine arts, in education, in temperance, in man's respect for his own body, in morals, in all those uses of life which are comprehended in the word civilisation. But of all the great triumphs in the intellectual domain, the greatest have been those achieved by the Engineer.

Just before the advent of our gracious Queen to the throne, the preparation of food, the making of clothing, the building of

houses, the distribution of the world's wealth, the going and coming between town and town in this country were, little different as compared with the conditions existing in the days of Charles the First or Queen Anne. As for education, in the manufacturing districts there were hardly any educational institutions at all for the children of the working classes except the Sunday Schools.

Poets have vied with each other in writing of this year of Jubilee. Odes and hymns have been composed, and among the many that have been written there is one beautiful verse by the Bishop of Ripon, which must go right to the hearts of Englishmen who have any knowledge at all of the difference between the present and the past:—

> For the priceless gifts of knowledge which by genius now are ours,
> For the ever-patient science which extended human powers,
> For the girdle which has girdled with quick sympathy the earth,
> For the intercourse of nations which checks the steps of dearth.

The Bishop's testimony to the development of human power and the discipline of force, is an eloquent recognition of the services of the engineer and of the civilising influences of his daily work.

THE GREAT LEISURE CREATOR THE STEAM ENGINE.

I think, that even Mr. Ruskin might be induced to agree, that the steam engine is the greatest creator of leisure invented by man. Although it might surprise those who have not thought much about it, yet I venture to assert—standing as I do here in the greatest centre of steam engines and mechanical appliances on the face of the earth—engines that save millions of foot-tons of energy every day—I venture to say that the leisure of the working people of this district is greater than that of any other people who have to earn their bread by the sweat of the brow. Which were the two cities that set the example to the manufacturing districts of the world that nine hours a day should be a day's work? Manchester and Glasgow did this, and yet it could never have been done without the help of those willing serfs—steam engines and mechanical tools. It has been done by the saddling and bridling of the forces of Nature for spinning and weaving and drilling and planing and

fetching and carrying in our workshops. And it seems only reasonable that when human labour is economised the labourer should profit by it. Men cannot become more civilised unless they have some period of leisure in which to think, and I claim for the engineers that they give men more thinking time, more time for the contemplation and enjoyment of those great works of art, the fame of which will live on through the ages, and a splendid representation of which is to be seen in this Jubilee Exhibition. I have no wish, and it would not be wise, to attempt to detain you this sunshiny afternoon with observations at any great length.

GREATEST MACHINERY EXHIBIT EVER HELD.

Let me say, however, that this Exhibition contains the largest and finest collection of machinery ever brought together under one Exhibition roof. The department comprises 135,000 square feet, this being about 60 per cent. more space covered than that occupied by machinery at the Inventions and the Liverpool and Edinburgh Exhibitions all put together. I suppose that the greatest exhibition of machinery ever held under one roof before was on the occasion of the great Exhibitition of 1862; and yet this Jubilee collection of machinery covers fully 50 per cent. more space than the Exhibition of 25 years ago. The Committee had a heavy responsibility in making the selections. But we know that the chief manufacturers of this district are well represented. The engines of Bolton and Hyde, the textile machinery of Oldham, and the mechanical tools of Manchester are represented by the finest examples, triumphs of skill and design. Even Salford is represented in a small way at this Exhibition. (Laughter and applause.)

SHALL ANY SURPLUS BE DEVOTED TO UTILITY AND BEAUTY.

I see that Her Majesty's Government intend to devote some attention to the promotion of technical education, a committee being appointed to further examine the methods employed in this country with that object.

About the beginning of the Queen's reign Lord Macaulay said:—"In this progressive country we neglect all that knowledge "in which there is progress, to devote ourselves to those branches "in which we are scarcely, if at all, superior to our ancestors.

"In this practical country the knowledge of all that gives power "over Nature is left to be picked up by chance on a man's way "through life."

If when this Exhibition terminates it should be the good fortune of the Executive Committee to have a surplus, it may not be an improper thing to indulge a hope that some portion of the building and of the profits may be used to promote technical education, and that as a survival we may have a permanent Exhibition in the interests of utility and beauty.

THE MOST IMPORTANT DISCOVERY OF THE CENTURY.

As I observed at the outset, much has been written on the improvements, the inventions, and the discoveries that have distinguished the Victorian Era. I venture to say that, as time enables us to throw the difference between the work of one man and another into a far-off perspective, the greatest discovery not only of the present reign but of the nineteenth century will be acknowledged as that which has enabled us to weigh, measure, and calculate the value of force—that great discovery of our fellow-townsman Dr. Joule—the mechanical equivalent of heat.

It was on the 4th of August, in the year 1843, that Dr. Joule wrote his first paper announcing to the world his discovery of what he called the mechanical value of heat; and, judging from the two standpoints of originality and utility, I think that this is the greatest physical discovery since the time of Sir Isaac Newton. Its enormous value to engineers we gratefully appreciate and acknowledge, but it does seem remarkable, that, in the book recently published, on the reign of Queen Victoria, in the article by Professor Huxley on science, although this great discovery and its value are described, the discoverer is entirely ignored—the name of James Prescott Joule not being mentioned in the book. As Professor Huxley truly says, before the year 1843 the conservation of energy had been approached, and he mentions Bacon's guess-work and gives the names of some of the minor workers in the field, but the greatest of them all is left unnamed.

After the mention of this great discovery, I am sure there is no one here who would not consider it a privilege to see the very piece of apparatus used by Dr. Joule in the experiments

which led him to the exact determination of the Mechanical Equivalent of Heat. It is contained in a Collection of Relics of Chemical and Physical Discovery, specially made by Mr. G. Watson Smith, the Vice-Chairman of the Chemical Section of our Royal Jubilee Exhibition, at the suggestion of my friend Mr. Levenstein, the Chairman of the Section, which will be found close to the fluorescent fountain in that Section. In this most interesting exhibit you would also see some of the very first experimental Safety Lamps made by Sir Humphrey Davy, when feeling his way towards a solution of what had then become a question of life and death for our coal miners. You will also find barometers, hygrometers, and other physical apparatus used by Dr. John Dalton in his experiments, amongst them even a common soda water bottle, now rendered sacred in having been pressed into Dalton's service. Although now there is no form of gas that can be called permanent, and that cannot be liquefied by high pressure, given a certain limit of temperature, yet in the earlier days of Michael Faraday, even ammonia gas had never been liquefied. But Faraday found that by dint of cold and pressure he could reduce to the liquid form quite a number of bodies hitherto regarded as permanent gases. You may in this collection see a series of such liquefied gases that were thus for the first time rendered liquid by Faraday, preserved in the very glass tubes in which he sealed them up. I may just point out that in the liquefaction of ammonia, Faraday laid the foundation for the cheap manufacture of ice on the large scale, and thus gave impetus and scope for the production of ice machinery now so largely used in many industries.

THE DISTRIBUTION OF FOOD THE ENGINEERS' NOBLEST FUNCTION.

Before concluding, gentlemen, I will refer in very few words to one great work of the engineer which is so pointedly brought before us in the last of those lines of the Bishop of Ripon which I have already quoted

> For the intercourse of nations, which checks the steps of dearth.

It appears to me that in facilitating the distribution of food the engineer is performing his noblest function, to-day the poorest in the land can partake of the products of the world's gardens, the sun shines 24 hours a day for those who have

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STEAM BOILER LEGISLATION.

So much have we come to recognise what I may call mental ·spitality, as the very foundation, the chief cause of British ogress—so unmistakeably has intellectual freedom placed the ıglish speaking races in the front rank as the mechanical ventors of the world—that any attempt on the part of our v-makers to restrain or hamper the engineers in the conduct their trade could have no chance of being tolerated, unless were plainly in the interests of public safety. Our marine lers are placed by law under the control of the Board of Trade, d although the conditions imposed by that potential depart-nt are sometimes aggravating and cause delay, yet, measured results, I think it is not too much to say that English steam ıts, including boilers and equipment, have been very much ıefitted, as a result of the action of that department.

The administration of the Alkali Works Acts, by the late Angus Smith and his colleagues and successors, it is erally admitted, has not only resulted in a great mitigation the production of gases prejudicial to public health and etation, but those who had been infringing the law have ı prevented from letting their waste products disperse to the ıry of their neighbours; and thanks largely to their control, ch has exercised a sort of semi-paternal government, they e introduced condensing apparatus and other methods of isation, which have saved the chemical manufacturers of this ntry many thousand pounds sterling a year.

The Mines Regulation Acts may also be cited as an example easonable control, and one, too, which is frequently found be in the interests of the employers as well as of the men follow such dangerous occupations.

Then again, the Factory Acts which have been passed from e to time are now, I think, looked on as beneficial by all ons who know anything about the application of these laws he manufacturing districts.

But bureaucratic, stereotyped restrictions introduced into the workshops of those who are perpetually changing and experimenting, bringing out and inventing, say, new forms of engines and boilers, cannot be permitted without the severest criticism by the engineers of this country. Centralisation is unfavourable to the principle of variability, as all history shows. Arrested civilisation may be seen in the history of China and other nations, some of which are now little more than a name. Progress is only possible, and has only been possible, in those happy conditions where the force of law has gone far enough to bind the nation together; but not far enough to kill all variety and destroy the individuality of its citizens.

With these thoughts in my mind, I have ventured to the conclusion that it might serve a useful purpose to consider on this occasion the Bill which has been introduced by Lord Stanley, of Preston, for the registration and inspection of boilers. Lord Stanley, I have no doubt, will fully appreciate any assistance which may be derived from members of this Association by means of the discussion ensuing on this address. It is true the Bill has been withdrawn, but it is not at all abandoned, it being Lord Stanley's intention to re-introduce it next session, with a view to the appointment of a Select Committee and the bringing forward of an improved Bill as quickly as possible.

Before describing this particular measure, I may, in a very few sentences, indicate the course of steam boiler legislation.

In the year 1817 a Select Committee of the House of Commons considered "the means of preventing the mischief of explosion from happening on board steamboats, to the danger or destruction of His Majesty's subjects on board such boats." This Select Committee made many recommendations, the chief of which were,—that all steamboats should be registered; that all boilers belonging to such should be composed of wrought-iron or copper; that all boilers should be tested, that they should have two safety valves each, and that a penalty should be inflicted on any person placing additional weight on the safety valve.

In 1839 there was another inquiry by the Lords of the Committee of the Privy Council for Trade, in consequence of

numerous communications made to Her Majesty's Government of the frequency of steamboat accidents. The Commission recommended a system of registration and periodical surveys, with regulations about safety valves, it being further recommended that on and after a certain date, following the passing of the Act, no steamer should be permitted to ply unless it had glass water-gauges and mercurial pressure gauges. Various other regulations were recommended.

Since then several Acts of Parliament have been passed, and marine boilers have been placed under the control of the Inspectors of the Board of Trade; so that no vessel carrying passengers is now permitted to go to sea unless its boilers have been examined and certified by a Board of Trade engineer. In the event of an explosion, an examination of the exploded boiler and investigation into the cause of the disaster must be made by the Board of Trade engineer and surveyors; and, if thought desirable, a formal inquiry instituted, the Court being presided over by the Wreck Commissioner. On the conclusion of such enquiry, a report is sent to the Board of Trade, containing a full statement of the case, according to the regulations imposed by the Steam Navigation Act of 1851 and the Merchant Shipping Acts of 1854 and 1876.

No legislation controlling the use of steam boilers on land took place until the passing of the Boiler Explosions' Act of 1882—a measure which was introduced by the late Mr. Hugh Mason, which was blocked by Mr. Wharton sixteen times, and which received the Royal assent on July 12th of that year. It is entitled "An Act to make Better Provision for enquiries with regard to Boiler Explosions." Since the passing of this Act, five interesting volumes of reports have been published, in which detailed accounts are given of the causes of the explosions. It is provided under this Act that when an explosion takes place, notice must be given to the Board of Trade by the owner or user of the boiler, under a penalty not exceeding £20; the Board of Trade may then appoint one or more competent engineers to make a preliminary enquiry into the cause of the explosion, the investigation to be held in open court. This court has power to make an order that the costs and expenses of the preliminary enquiry shall be paid by the person through

whose fault the boiler has burst, but I am not aware that such an order has yet been made. It seems that this Act of 1882 simply makes better provision for enquiries, and does not enforce the inspection of boilers.

I will now give a summary of Lord Stanley's Boiler Registry and Inspection Bill, which came before the House of Lords in the last session. The second reading of the Bill has been taken, not so much, however, by way of affirming all the details or even all the principles of the measure, but as recognising the necessity for the inquiry which will be held by a Select Committee of their Lordships' House during next session.

There are fourteen clauses in the Bill. It is proposed to enact that all boilers to which the measure applies shall be registered and bear a consecutive number, which must at all times be visible, and either dealer, owner, or user must give notice that he has in his possession a new or second-hand boiler; in default of so doing he shall be guilty of an offence which may be visited by a penalty under the Act. A penalty attaches for not making the number visible at all times. A new owner must, within fourteen days of possession, give notice that he has acquired a boiler. A register of numbers is to be kept by an officer of the Board of Trade. The only provision for the publication of this register is where it is stated that it may be admissible as evidence in case of a legal inquiry.

The owner of a boiler may nominate a competent person to superintend the working of the boiler, the name of such person being notified to the Board of Trade. It shall only be lawful to use a boiler after it has been inspected and a certificate obtained. The certificate shall state the duration of time in which the boiler may be used; if a boiler is used without such certificate, the owner will be liable to penalties. A committee may be appointed by the President of the Board of Trade for the purpose of advising on rules for the survey of boilers, and the fees of this committee, and all travelling expenses and allowances, may be taken out of the fees and poundages paid to the Board of Trade under this Act.

Clause 8 states who may be the surveyors of boilers under the Act. Any society, company, or body of persons whose rules for

the survey of boilers are for the time being approved by the Board of Trade (in this Act referred to as an approved boiler inspection society), may from time to time appoint surveyors, and assign to them such remuneration and such travelling and other allowances as may be sanctioned by the rules. "The Board of Trade, when satisfied that in any place in the United Kingdom there is no adequate provision by any approved boiler inspection society for the proper survey of boilers, may from time to time appoint competent surveyors of boilers for the purpose of inspecting boilers in that place, and may remove any surveyor so appointed." "Every surveyor shall execute his duties in accordance with the directions of the body appointing him, but subject to the boiler survey rules of that body, and a reference in this Act to the body appointing any such surveyor shall mean the Society or the Board of Trade, as the case may be."

Details are given of the methods and proceedings on the survey of a boiler before a certificate is granted. It appears that the period during which a boiler may be safely used must not exceed twelve months, or any less period specified in the declaration of fitness, and a duplicate of such certificate shall be forwarded to the Registrar, according to the prescribed regulations. If any boiler owners are dissatisfied, they may, if they think fit, cause a fresh survey of boiler to be made by one or more surveyors. If an owner is still further dissatisfied, his ultimate Court of Appeal is again the Board of Trade, who may appoint another competent engineer to report.

The Board of Trade may cancel a certificate if they think it has been obtained by fraudulent or erroneous declaration of fitness. Surveyors may be punished for accepting bribes or fees, or making false statements. Penalties attach to all owners of boilers who permit extra weight to be placed upon the safety valve after a certificate has been obtained. The Board of Trade reserve to themselves the power to make fresh rules, to rescind old rules, and to vary the rules for carrying this Act into effect. All rules, however, after being approved by the Board of Trade, must be laid before Parliament within three weeks after they are made, if Parliament be then sitting. Boiler inspection

societies are to pay to the Board of Trade one shilling of every pound such societies may receive. The measure is intended to apply to every boiler used within the United Kingdom, whether on land or afloat, with the exception of locomotive boilers, or any boilers belonging to railway companies, or any boilers used exclusively for domestic purposes, or those used in the service of Her Majesty. Any class of boilers, or the boilers of any district, may be declared exempt by an Order in Council. The term "boiler" is to be taken as meaning any closed vessel which is used for generating steam, or for heating water, or for heating other liquids, or into which steam is admitted for heating, steaming, boiling, or other similar purposes, and includes all the setting, equipment, and fittings of a boiler.

Provision is made for the constitution of the Committee, the members being drawn from Lloyds', from the Institution of Mechanical Engineers, the Institute of Civil Engineers, approved Boiler Societies, or from those whose names may be submitted by boiler makers in the United Kingdom, and four members may be placed upon the Committee, selected from persons who use steam power.

It will be seen, then, that this Bill makes provision for utilising the present boiler insurance companies and the associated steam users' organizations for boiler inspection and registry purposes; and in order to give due elasticity to the governing rules, the Board of Trade may appoint a lay committee, comprising users of boilers and members of scientific societies, who shall assist in the administration of this department—a committee which, it may be hoped, will render good service in regard to the revision and alteration of laws and regulations which might otherwise prove a vexatious interference with the business of users of steam power. This I look upon as a very good provision, but it probably might be better still if it were made somewhat wider in its scope. On this clause of the Bill especially, I invite your criticism. The definition of a boiler, it will be observed, is any closed vessel which is used for generating steam, or for heating water, or for heating other liquids, or into which steam is admitted for heating, steaming, boiling, or other similar purposes, and includes all the setting, equipment, and

fittings of a boiler. This is a definition which I think must receive further consideration, or otherwise it seems as if the inspector is destined to permanently live in some of the calico printing, bleaching, and manufacturing chemists' works in this district, where there is a great deal of boiling and heating by means of steam in all sorts of vessels.

It has been urged by those who object to the present system of boiler insurance that it is a system of purchasing indulgences; that some of the insurance companies simply receive the fees and do not make proper inspections; whilst at the same time they take all risk from the shoulders of the boiler owners by paying compensation in case of accident. The Trades Union advocates look for safety in a system of registering the boiler attendants, no person to be permitted to tend a boiler unless he has undergone the ordeal of examination and obtained a certificate. By this Bill of Lord Stanley's it is proposed, instead of giving a certificate to the man, that a certificate shall be given to the boiler.

Lord Stanley's Bill, no doubt, may be more or less improved in its details; but taking it altogether, I think it may be said that the President of the Board of Trade has shown a strong desire to deal with steam users very fairly. He has received advice from the Boiler Companies and the Steam Users' Association, and he is prepared to receive further recommendations from those who have the control of steam boilers. The Bill appears to rest on a basis of common sense and public utility which—subject, as I have indicated, to the amendment of some of its details—should commend it to the favourable consideration of users of steam power.

DISCUSSION.

The PRESIDENT said, as an introduction to the discussion, he would read the following communication from Mr. BOSWELL, who through an important engagement was unable to be present that evening:

I much regret to find that an engagement of long standing will prevent my being present at the opening of the Session, when our worthy President will give his Address on "Steam Boiler Legislation." The subject is one with which I am somewhat closely connected, and to which I have devoted considerable time and thought. I have had a number of copies of my "21 Years' Boiler Explosions'" list struck off, and take the liberty of sending a few for distribution at the meeting, and I also venture a few remarks on the Boiler Registry and Inspection Bill. There can be no doubt whatever that the President of the Board of Trade has a very strong case indeed, and needs to make no apology for introducing the Bill now presented. The time has arrived when the public must have protection, and the unscrupulous boiler owner must be compelled to take the responsibility of indiscreet conduct, and not be allowed to plead ignorance and escape justice, as has been the case so often. Passenger-carrying steamships, collieries, railways, the manufacture, use, and storage of all kinds of explosives are now under special restrictions, and none of these are more dangerous than a steam boiler in the hands of skilled malice or an unscrupulous boiler owner. How to give the public that much needed protection is the difficulty now to be overcome, and Lord Stanley of Preston, has acted wisely in placing before the public his first draft, so that it may be freely commented upon and criticised, such comments and criticism being of use in guiding him in his future course.

The Bill is certainly only a first draft, and must needs be modified and toned down before it will become law, but the framework often foreshadows the finished structure, so may we read between the lines the ideas and wishes of the promoters of the Bill, who are no doubt being guided by their experience in the working of the Act of 1882. The registering of all boilers and similar vessels will no doubt be an absolute necessity, but whether this will be of much use without inspection is open to grave doubt; certainly no one would be allowed to make, use, buy, sell or transfer a boiler without the same being duly recorded, but will this tend to reduce the loss of so many valuable lives, which in 1885 was no less than 33 killed and 57 injured? The working of the Act of 1882 shows unmistakably that what is required in order to keep down explosions is efficient inspection, to procure which further legislation is required, and from the pretensions of the present Bill I see no cause whatever for the serious apprehensions entertained by so many. There are two distinct classes of boiler owners which, for clearness, may be described as the scrupulous and the unscrupulous; the former need not fear the effects of the Bill, as it is not likely to act in any way against their interests or present line of procedure of placing boilers under the care of experts, while with the latter, from whom the greatest cry is heard, and with whom mainly rests the responsibility of the present great loss of life, the Act will have a most beneficial effect. That the Board of Trade do not desire absolute control is made manifest in asking for a lay committee, which if composed as suggested in the Bill, cannot fail to hold that knowledge required in the framing of rules for the working of the Act. Why railway companies are to be exempt is not easy to see, their records not being of the best. The charges for inspection, and status of inspector, and several other matters, may I think be left with confidence to the committee. One good clause is every boiler must in future have a responsible agent.

Mr. R. Rawlinson thought that the proposed Bill was simply a means of increasing the number of Government inspectors, who were becoming a positive hindrance to commerce, and of

the free development of the engineering profession. He was of opinion that our ordinary insurance inspectors, with their experience, were far more qualified to deal with the subject than were the Government gentlemen who in the majority of cases were utterly incompetent to deal with many questions under their supervision. He did not object to the present inspectors being called upon to register their certificates and reports with some government or county board under a number.

Mr. James Walthew said that the subject before them would probably give rise to much discussion. They could not close their eyes to the fact that in many instances explosions occurred, and great destruction of life and property ensued, by working boilers at pressures considerably above the limit they were really capable of carrying. The question was how were they going to prevent them without some form of compulsory inspection. Voluntary inspection had now been in vogue some years, and without doubt good results had accrued to the public, and even to boiler makers, from the efforts of those voluntary associations. Unfortunately there were sections of steam users who regarded with indifference the simplest laws of prudence in this or in other matters. The remedy for this apathy or neglect, he contended, was to insist upon all boilers being periodically inspected by an efficient authority, and to his mind the measure under discussion was worthy of the support of every individual who was in any way desirous of seeing an end to the present state of things. The clause in the Bill limiting the time of working to one year after granting certificate might, he thought, be safely extended to two years, in many cases it being inconvenient to stop in that space of time.

The President remarked that the primary examination would enable them to form an opinion on the quality of the boiler.

Mr. Joseph Nasmith said that after surveying the several clauses of the Bill he had come to the opinion that it was only

another step in the sort of Government interference, and the formation of close corporations, which certainly seemed to be taking place in all professions. First they had the Accountant Society, into the inner circle of which no outsider might enter, and now even the various patent agents were clamouring for the same privileges, and altogether there seemed to be a tendency to encourage legislation which should make close corporations of almost every profession and trade, eventually making it absolutely impossible for any man to enter into one unless he had the goodwill of the Committee who regulated it. Only recently there had been a proposition for the registration of plumbers. Now in his view, in the greatest freedom there was the greatest safety, and if a man were treated as if he were a being who ought to know what he was doing, and be held responsible for the safety of every tool he might use, a much better result would be gained than by the adoption of any elaborate system of Government control. His remedy, in fact, was where a boiler exploded the owner should be made to prove to the court that he knew, or had reason to know at the time of the occurrence, that it was in good condition. He was not supposed to keep the certificate provided by the Bill carefully framed and put away, because they knew from experience that boilers from various causes deteriorated in some instances in much less time than a year, the period which the certificate was supposed to cover. If a man exercised the ordinary care for a boiler, considering the consequences of an explosion, any defect would be found out during the time, and if they granted him amenity on account of having that certificate, he was to a certain extent freed from responsibility for any disaster which might arise. He contended that instead of appointing Government inspectors, that it should be made compulsory on boiler owners to have boilers inspected, at the same time leaving it to their own discretion as to the Company they might choose to undertake that duty, and if at all times they could prove that the inspector's recommendations had been carried out, it would be equivalent to the proposed certificate. If the certificate were granted it would be simply the means of removing from the owners that criminal and civil responsibility which they ought to have, and in fact throwing the shadow

their weak construction in time to give warning of the danger and prevent explosion. As far as could be ascertained, about half the boilers in the country had been placed under periodical inspection voluntarily. Inspection had now been well tried. The Manchester Steam Users' Association was founded in 1854, and inspection had been extending ever since, and was now adopted not only in Europe, but in America and the Colonies. It was therefore no new untried scheme, but an established and approved institution. Under these circumstances it would seem no hardship to enact that the inspection of boilers should be adopted generally, and that one half of the steam users in the country should in the interest of the public safety adopt the simple precaution that the other half had already adopted of their own accord.

At the present time he knew of no law which could prevent a man working a boiler in any part of a crowded city, even though the boiler might be in a most dilapidated condition, or the safety valve lever fastened down. At Leeds, as an Inspector of the Manchester Steam Users' Association was passing through a public thoroughfare, he saw a portable engine employed at some sewage works, and on examining it found the safety valve locked fast. As there was no other safety valve the boiler was practically without any safety valve at all, and could only be worked at imminent risk to all passers by. Equipping boilers with safety valves loaded with spring balances so arranged that a few extra turns of the thumb-nut locked them fast had proved a fruitful source of explosion. At Dublin a house was brought down, and fourteen people buried in the ruins and killed by the explosion of a boiler in a foundry alongside. The plates of the boiler were found after the explosion to be wasted away by external corrosion till no thicker at the primary rent than a knife edge. These were simply two illustrative cases shewing the danger to which the outside public were exposed from proximity to badly constructed or badly conditioned boilers, over which they had no control, and of the very existence of which they might be ignorant. The records of the Manchester Steam Users' Association contained long lists of such cases, many of which had proved very destructive both to life and property. Time, however, forbade further reference thereto on that occasion.

Mr. Hick's Select Committee of the House of Commons, which was appointed to investigate the causes of steam boiler explosions, made the following statement in their report :—

> "Your Committee cannot omit to emphasise the fact that steam boilers are in many instances situated in much-frequented parts of towns and cities; under pavements in crowded thoroughfares; in the lower storeys of houses; and in the midst of crowded dwellings. That these boilers are often faulty in construction; are frequently so placed that inspection without removal is impossible; are without proper gauges and necessary equipments; have exposed safety valves, whereby the pressure can be increased to a dangerous extent by anyone having access to the boiler . . . . . ."

Under these circumstances, seeing the great loss of life that had resulted and continued to result from steam boiler explosions, and the danger to which the public were constantly exposed, he thought the meeting would allow that some action should be taken. They now knew that the mysterious causes to which explosions had been attributed in old times were altogether imaginary, and that the majority of explosions could be prevented by inspection. With this knowledge of the cause of explosions, and how to prevent the sacrifice of life, already referred to, they were bound to use it.

What then was to be done? There were various propositions.

One proposition was, to certificate the boiler attendants, and not to allow anyone to mind a boiler who had not passed a Board of Trade examination and received a diploma. This implied that the responsibility of explosions lay at the door of the boiler attendants. Such however, was not the case. It was an unfair aspersion upon their character. The Manchester Steam Users' Association had investigated nearly every explosion that had occurred throughout the United Kingdom for upwards of a quarter of a century, and had found that the majority of explosions were due to bad boilers and not to the neglect of the attendants. For every explosion due to the neglect of the attendant four were due to the neglect of the owner in not getting a good boiler in the first instance, or in not having it suitably repaired in the second. Thus the *Boiler* needed examination rather than the *Attendant*.

Another proposition was to inflict punishment on the owner in the event of an explosion. He thought the infliction of penal-

ties would be a step backwards. We had of late years been endeavouring to reduce our Criminal Code. We had given up hanging for sheep stealing, and given up the pillory and the stocks. We had adopted schools instead of gaols, parks and recreation grounds instead of Botany Bay and the Hulks. Let them not go backward. Let them not invent a new crime, but adopt a kindly system of inspection which, instead of punishing the boiler owner, would help him to protect his property and save the stoker's life. Even if punishment were resorted to, it would be very difficult, if not impossible, to bring the responsibility home to the right party. The owner would throw the blame of the explosion on the manager, the manager on the mechanic, and the mechanic on the stoker, and the weakest would go to the wall. That would not meet the ends of justice, or promote the interests of the public safety. Prevention would be found much more efficient than Punishment.

Assuming that prevention were adopted instead of punishment, and the adoption of inspection enforced by law, the question might be asked, how should it be carried out? The Manchester Steam Users' Association had always been opposed to the inspection of boilers being placed in the hands of the Board of Trade, and it objected to that still; but it thought that the Government could enact that every boiler in the country should be placed under inspection, without making the Board of Trade the inspector. The proposal in Lord Stanley's measure was that the inspection of boilers should be conducted by *lay institutions*, such as the Manchester Steam Users' Association and the Steam Boiler Insurance Companies; and not only so, but by any similar institutions that might be founded in future. But in order to secure the integrity of the inspection and prevent commercial competition from destroying its value and efficiency, rules would have to be laid down for the regulation of the service, and these rules would have to be enforced by some central authority. It was not, however, proposed that these rules for the conduct of the service should be drawn up by the Board of Trade, lest any harshness or rigidity should creep in which would be uncongenial to the steam user, but that they should be drawn up by a *lay council*,

consisting of steam users and engineers conversant with the manufacture and working of steam boilers. Gentlemen in the meeting might have seats on that lay council. It would be, as they would see, a description of Steam Board or miniature Steam Parliament. The Board of Trade would take the duties of the executive, and see that the rules laid down by that legislative body were carried out. Thus steam users would legislate for themselves.

It had been supposed by previous speakers that the cost of inspection would fall upon the British taxpayer. This, however, was a mistake: it would be entirely defrayed by the boiler owner, as at present. Everyone would pay for the inspection of his own boiler.

Not only would inspection save human life, but it would tend to correct unfair commercial competition. It would prevent unscrupulous makers from using inferior material in the construction of their boilers, and would thus protect those who were fair dealing, who used good material, and whose workmanship was satisfactory. In this way it would put competition on a fairer basis. It would improve the general standard of workmanship and material. It would level up. The importance of this he thought all engineers would agree with.

He would only add that this must not be mistaken for a measure for promoting the Governmental inspection of Boilers. On the contrary, it was a buffer against Governmental encroachment. It was a measure for promoting self-help, self-government. *It was a measure for putting the inspection of boilers into the hands of steam users themselves.* It was thought it would be wiser for engineers and steam users to take advantage of the present opportunity for consulting together and drawing up some judicious measure for securing efficient inspection without harassing the steam user, rather than to let things drift along until they were legislated for by the Government and had a measure forced upon them which they did not approve.

Mr. J. West observed that it seemed to be fairly unanimous on all sides that there should be compulsory inspection, the only question being as to how it should be enforced. To his

mind that should certainly emanate from the Government, who might appoint local representatives of the various inspecting companies. He regarded the supervision exercised by the various insurance companies as of immense value, especially in large undertakings, say like the Manchester Corporation with its multifarious boilers, where it was impossible to fix the responsibility on any individual; and certainly, when he was Chief Engineer of the Gas Department of the Manchester Corporation, he was much relieved by that responsibility being undertaken by the Steam Users' Association and other insurance companies. As regarded the alleged ignorance of the attendants, his own personal experience was that the men were fairly well informed in the details of their work, which conclusion he had been able to come to from personally visiting the men, and verifying any complaints or statements they had made with reference to their boilers.

Mr. James Hartley concurred with the objects of the proposed Bill, especially the clauses for enforcing compulsory annual examinations, and to a certain extent with the nomination of a person to be responsible for the satisfactory preparation of the boiler for inspection, and for the keeping in working order of the necessary fittings. Compulsory examinations, he said, were necessary to protect some joint-stock boiler insurance companies—happily, not all of them—from insuring boilers with which they were unacquainted, in many cases not having inspected them, as also boilers which other companies had condemned as unfit to work at the then working pressure. The fact of the boiler being insured in such a manner scarcely ever became known generally unless the boiler exploded. Again, the public had a right to this compulsory inspection in order to be protected from having unsafe and defective boilers placed under crowded streets and warehouses, and also to protect the boiler owner, who annually had his boiler examined, from any loss by damage to his property by a boiler exploding in the works of his neighbour, who cared nothing about the safety of his boiler, there being unfortunately many such persons. Further, to protect the public from the many portable boilers which were in use at fairs, these latter being especially

ıbject to the action of the different kinds of water which 'ere used, as also from the carelessness of incompetent ;tendants. Traction engines should also be included, some of hich, he ventured to say, would on a thorough examination be ıund entirely unfit to work at the pressure which was carried ı them; these boilers being also very recklessly managed and ındered dangerous through the attendants tampering with the ıfety valve, &c. He saw from the Bill that locomotives were ;empted from inspection, but he himself thought that they ıould be included in the proposed measure. With reference) the time of examination, he thought, speaking generally, velve months was quite long enough for any boiler to work ithout thorough inspection, though in some cases even this ıight be too long. He might say that there was a practice 'hich prevailed in France which he should like to see adopted ı England. In the former country, on every safety-valve lever 'as attached a brass plate, stating its length, weight, and ılcrum: again, every valve of the open-lever type was stamped ıith its diameter. Further, on box valves the cover must have brass plate, giving the diameter of valve. Every external 'eight on a safety-valve lever must likewise be stamped with 's weight. Internally weighted valves had the weight tamped on the valve stand. Also, no boiler was allowed to 'ork without two safety valves and a metal tablet, placed in prominent position, indicating the pressure, which the boiler ıust never exceed. Those figures must positively be given, thus nabling the inspector to work out for himself the various articulars and check them, and further, the weight must in ny case be at the end of the lever. Respecting the many lasses of boilers, he was of opinion that it was absolutely ecessary that kiers, economisers, and rag boilers should be ncluded in the Bill, since when they were connected with the oilers they were practically the same as boilers. He approved f the Registration of Boilers because it would be effective in reventing old and condemned boilers being again set to work, s also of the fact that it must be done in 14 days, since n many cases persons bought second-hand boilers and set hem to work on the recommendation of the broker or seller, hough on examination they were found utterly defective.

He would also make it imperative that the maker's name and date of manufacture should be prominently shewn on every boiler, and he would deal severely with any person who erased or in any way tampered with those figures, as also with anyone who interfered with the safety valve. With reference to the rates charged for insurance and inspection of steam boilers, he said, to be efficiently done at from 10s. to 15s. per boiler (as some insurance companies professed to be able to do) was utterly impossible, and there was no wonder when explosions did occur that inspectors complained that they had not had time to thoroughly ascertain the condition of the boilers examined by them. Concluding, Mr. Hartley mentioned that the Blackburn Committee of Commerce had considered Lord Stanley's measure, and fully approved of it in every detail.

Mr. W. Lawson thoroughly sympathised with the objects of the Bill, since he thought that a very good case had been made out for new legislation on that important subject, at the same time he concurred to a certain extent with the remarks of Mr. Nasmith about the tendency to over-legislate. As a specimen of this over-legislation, Mr. Hartley's suggestion to include locomotives in the proposed enactment, he contended, was an example, because he believed it would be difficult to find in any other great commercial undertaking such immunity from boiler explosions as there was on our railways.

Mr. R. C. Longridge remarked that Mr. Fletcher seemed to be very certain that the Board of Trade would not entirely control the inspection of boilers, but he (Mr. Longridge) thought that eventually it would entirely fall into the hands of that authority. The President was to have the nomination of the members of the Committee, and it certainly did seem as if the Board were to be the ultimate authority in the matter. He did not know how much objection there might be to that, but he was doubtful as to the necessity for compulsory inspection, and for putting themselves into the hands of the Board of Trade. Mr. Fletcher had mentioned that probably half the boilers in the country were under inspection, but he (Mr. Fletcher) would probably not care to vouch for the accuracy of that statement, because as

a matter of fact the number of boilers in use was unknown. If they did not know the number of boilers in use they could hardly say what proportion of them were under inspection, and it seemed to him that it would be better to find out how bad things were before rushing into legislation. When they knew how many were under inspection, and how many were not, they could judge whether it was necessary to go to the trouble and expense of passing laws for compulsory inspection. Provision was made in the Bill for the working of the Act, but he was not sure what boiler owners would have to say about the fees to be charged. It had been said that the fee might be a couple of guineas per boiler, and boiler owners, he thought, would be mistaken if they supposed they would get inspection cheaper than they were having it at the present time. If they were to have compulsory inspection, he hoped it would be thorough and efficient in every respect, but such a scheme of inspection as was set forth in this new Bill was insufficient. It thereby provided for an annual thorough examination of each boiler while idle; but there were many serious defects which could only be discovered by inspection of the boiler while at work. In conclusion, Mr. Longridge said the Board of Trade had not fully exercised the powers conferred upon them by the last Act, the only result being the publication of reports, some of which were, to say the least, not what they might be.

Mr. Rawlinson pointed out that since 1865 there had been a very considerable increase in the percentage of boilers in use, and also of their horse power and of their working pressure, at the same time explosions had decreased in inverse ratio, so that under the present circumstances they were not altogether in the wrong path.

On the motion of Mr. J. Horsley, seconded by Mr. Jas. Walthew, a vote of thanks was passed to the President for his interesting address.

The President, in responding, suggested that a Committee of the Association might be appointed to consider the question which had been dealt with, and present a special report.

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)YAL JUBILEE EXHIBITION,

Manchester.

SHORT COMMUNICATION

BY

R. SAMUEL BOSWELL,

(Member of the Association,)

ON

terial Used in Boiler Construction,

22nd OCTOBER, 1887,

AT THE GRAND HOTEL, MANCHESTER,

THOS. ASHBURY, C.E., Past-President,

IN THE CHAIR.

MANCHESTER:
ALD & WALKER, PRINTERS, BACK POOL FOLD, CHAPEL WALKS.
1887.

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1887.

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MATERIAL USED IN BOILER CONSTRUCTION.

A few years ago the scientific atmosphere was so filled with ie fog of electricity, and our scientists themselves were so nbued with the same wonderful power, that the engineering orld became quite alarmed at the prospect of being snuffed ut, as it were, by this somewhat new and wonderful agent, lectricity. One great authority told a distinguished audience hat in less than 50 years the locomotive would only be seen in ome museum, as a relic of bye-gone ages.

This beginning of the end is however having a somewhat rolonged postponement, as up to the present this wonder-vorker has only become popular in one direction, and its only ffect on the steam engine has been to bring out and further levelop many of its finest qualities.

So long as steam is used, generators must be made to suit he required purpose, and it is to the samples of material for ise in their construction that I would call your attention o-night.

There is certainly not a very extensive display of this naterial at our Royal Jubilee Exhibition, but there are four tands where exhibits of interest are to be seen. On the tand of Sir J. Whitworth & Co. (No. 381) is to be seen an rticle that wins the admiration of all, but which I think annot be looked upon as an article of commerce. The Stand No. 617) of the Steel Co. of Scotland contains a manufactured rticle in daily request, so made and of such material that it is imply faultless. The Stand of Bolckow, Vaughan & Co. No. 600) shows several smaller articles which, as work done y hand, bring forth the praises of all practical men. The tand (No. 811) of the West Cumberland Iron and Steel Co. hows an article which is no doubt the best of its kind ever xhibited, in the form of a collapsed flue. Each steel maker an show test pieces, but few, if any, can show such an actual est as this flue has been put to. It is to be regretted that two f these exhibits are about 10 feet from the ground and beyond

close inspection. On the Stand of Sir J. Whitworth & Co. will be seen a solid weldless ring of fluid compressed steel, 12ft. diameter, 5ft. wide by about ¾in. thick, which by the way is a forging, and as such it is without doubt a wonderful piece of work, the difficulties to be encountered in the construction of such a piece of work being so numerous that the engineer in viewing this triumphant achievement may well stand amazed. I, however, do not look upon it in the same light as many, as it is yet something of the White Elephant kind, as it is outside its own sphere as a solid weldless ring that the greatest difficulties will have to be met and successfully overcome. I may be considered somewhat conservative in my ideas, but I really do not anticipate an immediate revolution in boiler practice, although I admit it may be the seed from which a bountiful harvest may come, and it may also render a practical solution of that vexed question—"Rivetted Joints." Both sides of this ring are left full of serations or flats, which would have to be removed before a metal-to-metal joint could be made, such as required in first-class boiler work; and with the tools at present in the hands of boilermakers I fear they could not with facility handle such rings, while a solid weldless ring, say 12ft. diameter and 10ft. long, such as would be required for an ordinary marine boiler, would have to be made at the waterside. Again, I am not sure that fluid compressed steel will meet all the requirements at present laid down by boiler authorities and now so successfully fulfilled by mild boiler steel, while the cost of fluid compressed steel is, and ever must be, a serious item. I would gladly say more on this, but time forbids.

The Steel Co. of Scotland exhibit their usual ordinary and special sections, but the masterpiece of their stand is the boiler half-end plate which spans their stand 12 feet from the ground, thus concealing that accuracy, minuteness of detail and finish which would be so inviting if within reach of inspection. Having had a favourable opportunity of inspecting this wonderful achievement by hydraulic machinery, I am perhaps better able to judge upon it than if I had only seen it as seen by the ordinary visitor. It is the lower half of a front end plate for a marine boiler 14ft. diameter, with openings flanged inward for four furnaces, each of which is 2ft. 9in. diameter,

with a flange 4½in. deep; round the outer edge for connection to shell is a flange 8½in. deep, the plate itself being $\frac{13}{16}$in. thick, weighing nearly 2 tons 7 cwt. Test strips from this plate give a tensile strain of 27·8 tons per square inch, and an elongation of 26·3 per cent. As a sample of work done by hydraulic machinery I believe this end plate stands second to none.

The Stand of Messrs. Bolckow, Vaughan & Co. shows several small articles, in the construction of which a great amount of skill and ingenuity has been exercised, and as work done by hand, can scarcely be excelled. Machinery is now adopted for nearly all purposes, especially flanging; but there will always be articles too irregular to be made in a machine, although a flange that is pressed into shape at one heat will always be better work than that done by the old barbarous method of repeated local heating and flanging with mallets, but small articles will for many years to come have to be flanged by hand. The articles specially worth notice here are one tube 9in. diameter with a flange on each end 5in. wide, two throat pieces, and a small end plate.

When taken from a boiler-maker's point of view, perhaps the finest exhibit is that of the West Cumberland Iron and Steel Co. (Chemical Section), in the form of a portion of a collapsed flue tube.

It is two plates connected by means of a flanged seam. The entire flue, of which the exhibit forms a part, was at work at a colliery, when by mistake it was allowed to get short of water. The result was overheating of the plates to such an extent as to cause their being forced down almost upon the bars. In thus being forced down the plates would not only be submitted to a hot bending test, as many would suppose, but they would also be subjected to a very high tensile strain, and as we all know that most metals lose their strength when hot, you will admit that it must be excellent material that will resist successfully such a test as here shown, in which the stretch of the metal has been 28 per cent without the least trace of fracture, the high tensile strain being fully illustrated by the manner in which the flanged seam has been crumpled up.

This is one of those cases which clearly proves the advisability of having flues well strengthened with anti-collapsing seams of one form or another, for had such not been the case here a serious explosion might have resulted. This is a most crucial test successfully resisted by that once doubtful, but now most reliable material, mild steel. I may say that I have seen many collapses, but none so severe and complete as this. This exhibit is on the top of a showcase, and consequently not in as good a position as its importance would suggest.

Taken together, the exhibits I have named should at the least have one effect, and that is, if there still are minds sceptical as to the qualities of steel, such sceptical opinions should at once vanish, particularly when we find that there are really no exhibits of iron to be found, probably because the iron maker does not dare to place his productions side by side with mild steel, now so much used in the construction of high-class boiler work.

DISCUSSION.

Mr. Ashbury pointed out that the ring exhibited by Sir J. Whitworth and Co. was merely a forecast of what might be expected in the future, and said that as a solid weldless ring it stood unique that day in the history of steel making. He thought it augured a great change in marine boiler making, since if they could minimise the number of riveted joints in a boiler it would be a great acquisition. He questioned Mr. Boswell's remarks as to the price being prohibitive of its use, since the excellency of material and work over the ordinary material would, in his opinion, be more than *quid pro quo* for the extra cost.

Mr. Rawlinson thought Mr. Boswell was getting antiquated in his ideas when he mentioned certain steel as representing a tensile strain of 27 tons, because the Whitworth steel had a tensile strain of 64 tons. That fact alone would inform Mr. Boswell of the manner in which they were going to get their pressure out of a $\frac{7}{8}$in. plate. With regard to the difficulties of

manufacturing, it was really too late in the present day to consider those as obstacles to progress.

Mr. Boswell said that the only gain would be in the shell, which might amount to 25 per cent., but this would only be the fact so long as the shell was kept free from corrosive wasting. The ends, furnaces, and stays would not be in any way affected by the weldless ring of compressed steel, therefore the weight of the finished article would only be reduced—say 10 per cent. Mr. Rawlinson did not seem to be aware that boiler authorities would not allow steel for boiler purposes to be used if it was capable of resisting a greater tensile strain than 32 tons; hence was a question of mildness rather than tensile strength. Again, fluid compressed steel was yet wholly untried for this purpose, and until more was known of its price and qualities it could scarcely be expected that any firm would lay down new plant for handling the weldless rings. Certainly no firm at present could handle them with facility, and the railway companies could not carry them above a certain size, while in any case special trucks would be required, again tending to increase the cost. Considering all points, Mr. Boswell thought that, so far as he could see, 100 per cent. extra would have to be paid for a gain of 25 per cent. in strengh, or 10 to 20 per cent. reduction in weight.

On the motion of Mr. W. Lawson, seconded by Mr. T. Daniels, a vote of thanks was unanimously passed to Mr. S. Boswell for his contribution to the records of the Association.

Mr. Boswell suitably acknowledged the vote.

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ROYAL JUBILEE EXHIBITION,

Manchester.

SHORT COMMUNICATION

BY

MR. THOMAS ASHBURY, C.E.,

(Member of the Association,)

ON

LOCOMOTIVE ENGINES,

22nd OCTOBER, 1887,

AT THE GRAND HOTEL, MANCHESTER,

MR. THOS. ASHBURY, C.E., Past-President,

IN THE CHAIR.

MANCHESTER:
HERALD & WALKER, PRINTERS, BACK POOL FOLD, CHAPEL WALKS.
1887.

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1887.

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LOCOMOTIVE ENGINES.

will now ask you to do me the honour of accompanying in your imagination, to the Royal Jubilee Exhibition at Trafford, Manchester, and it will I think impress us all t in the "Still Machinery" Section of the exhibition the st striking and imposing exhibits are undoubtedly those of Locomotive Engines. We will also take the two locomotives ch are shown in the Irish Section, and for our purpose sider that no separation or dis-union exists, but that all are t of the "Still Machinery" Section.

Altogether therefore we find that there are on exhibit nine omotives, and these are so diversified in design and con-ction that they form an excellent combination illustrative modern locomotive building, and (excepting the two Irish gines) they may all be considered as local exhibits. Many of m having been built under the direction of some of our own mbers, it is not at all out of place to call the attention of members generally to the salient points of interest in the spective locomotives that have been on exhibition at Old afford during this Jubilee year.

We will give the Irish exhibits the first notice, and the small amway Engine built and exhibited by William Spence, of blin, is certainly very peculiar looking, and to us it is an familiar style of engine, and as it is nameless, its appearance ggests that "The Ferret" or the "The Ratter" might be propriate names to give to this strange-looking novelty. wever, it has been carefully designed to meet special ditions in work through low and narrow tunnels. It has r coupled wheels, 1ft. 10in. dia., a 3ft. wheel base, working a 20in. guage. The cylinder and crank shafts are *above* the ler, and the crank rods are vertical and coupled to the nk pins on the hind wheels.

The engine rests on a flexible spring bogie, and for shunting rposes the engine and boiler can very readily be lifted off the row guage bogie and put on to a 5ft. 3in. guage bogie.

The cylinders are 7in. dia., 8½in. stroke; steam pressure,

180lbs.; weight, 7¾ tons. Power equal to a load of 120 tons at the least at ten miles an hour, or a load of 25 tons up a gradient of 1 in 40.

Mr. Ceoghegan, of Dublin, is the patentee of this engine.

The Great Southern and Western Railway Co., Inchicore Works, Dublin, send a fine specimen of their newest Express Passenger Engine and Tender, such as are in daily use in the Dublin and Queenstown American Mail Service. This engine, built under Mr. Ivatt's superintendence, is similar to those designed by his predecessor, Mr. Aspinall. The cylinders are 18in. dia., 2ft. stroke; four wheels coupled, 6ft. 6in. dia., with a four-wheeled bogie; steam pressure, 160lbs. per square inch, total heating surface, 1,068 sq. ft.; firegrate area, 18¾ sq. ft.; engine boiler, 39 tons 4cwt.; tender loaded, 28 tons 6cwt.; water tank, 2,700 gallons capacity. Though there is not any distinct novelty in this engine, it is a highly creditable specimen of locomotive work, and will bear rigid inspection, as will also some rough engine forgings and castings beside it. I may remark that both the small engine and the larger one have not been made specially for this exhibition, but both of them were taken from actual daily work, and after a thorough cleaning up sent on to Manchester.

Following the order of the smallest engine first, in the "Still Machinery" Section, we have a very bonny and elegant little engine called by the pet name of "Dot," designed for use in the L. & Y. Railway Co.'s new locomotive workshops and yards at Horwich, and in the works of its makers, Messrs. Beyer, Peacock & Co., Limited, Gorton.

This miniature, yet symmetrical engine is made for an 18in. guage, with outside cylinders 5in. dia. and 6in. stroke; four wheels coupled, 16¼in. dia.; wheel base, 2ft. 9in. The boiler is 4ft. 3in. long by 2ft 3in. dia., with 55 tubes, and is made to work in with the rest of the engine in due proportion to its work. The water tank has a capacity of 25 gallons. Extreme length of engine is 7ft. 5¾in. and extreme width 3ft., and its total weight in working order is 3 tons 5cwt. This engine is very suggestive not only of much economy, but of quick despatch and great facility in the moving of material from place to place in large works and establishments, and the experience gained in the works named affirms the successful

application of this form of motive power for haulage.

We next notice a very fine example of a Colonial Tank Engine, designed for the New Zealand Midland Railway, and as anything affecting the progress of our colonies is of interest, I may be pardoned for giving some details of this latest design of a Colonial Railway Locomotive, built by the firm of Nasmyth, Wilson & Co., Limited, Patricroft. The engine, which is for a 3ft. 6in. guage, was designed by Mr. Robert Wilson, of London, for service on a railway having stiff gradients for about 10 miles (one length alone being 3 miles), with curves of 300ft. radius and on inclines which average 1 in 40. The engine carrying water enough for the 10 miles run is able to haul a load of 70 tons gross—exclusive of its own weight—with perfect ease, at speeds of 25 to 30 miles per hour, and to stop and start readily on any point of the incline.

This engine, which complies with all the conditions demanded, weighs in full working order 24 tons.

The engine is of the outside-cylinder type, the wheels also being outside the frames.

It has four wheels coupled 3ft. 9in. dia., and a four-wheeled bogie in front with wheels 2ft. 2½in. dia., having crucible steel tyres. The wheel centres of the coupled wheels are of wrought-iron, and the bogie wheels of steel, forged solid and machined to shape. The cylinders are 12in. dia. 18in. stroke. The valve faces being inside the frames, the valves are actuated by Stephenson's link motive direct.

There is only one slide bar fitted to each cylinder, and it is placed above the cross-head in order to prevent as far as possible the wear and tear caused by sand, &c., and also for this object the connecting and coupling rods are also fitted with closed ends in the steps.

The axles are best crucible steel, with extra large bearing surfaces. The axle boxes are made from forged steel and fitted with bronze steps.

The horn-blocks are of cast-steel fitted with wrought-iron adjusting wedges.

The frames, which are ⅞in. thick, are planed all over and are in one solid piece.

The wheel base of the coupled wheels is 6ft. 10in. and the bogie wheel base 4ft. 9in., the total wheel base being 16ft. 9¼in.

The boiler is telescopic, each ring in one plate, with butt joints, with inside and outside cover plates, double rivetted. The diameter is 3ft. 3in. and the length of the boiler is 8ft. The fire-box shell is 4ft. 6in. long and 2ft. 11¼in. wide at bottom, the water space at bottom being 2in. The total length of boiler and fire-box is 12ft. 6in. There are 121 brass tubes, and the inner fire-box is of copper, with a heating surface of 53 square feet above the fire bars. The boilers have a heating surface of 457 square feet, making a total of 510 square feet.

The smoke box is elongated and is upon the latest principle, fitted with hinged perforated plates, &c., for arresting sparks, cinders, &c.

The Ashpan is water tight to hold 1½in. depth of water, for extinguishing the falling cinders.

Two of Gresham and Craven's injectors, with all the other usual fittings, are neatly and conveniently arranged inside the cab, which is a model cab for the protection and comfort of the driver and stoker in all kinds of weather, whether intense heat or cold, rain or sunshine.

The bogie is made on the swing bolster system, which avoids the use of lateral springs for controlling the bogie.

The drawing and buffing gear is combined in the central system, and is specially arranged so as to take the pull from a point as near the coupled axles as possible. And to allow the gear to follow the sinuosities of the railway, suitable springs are arranged, which restore the drawbacks to a central position when the engine is again on a straight road.

A substantial cow catcher is placed at both ends of the engine.

The four coupled wheels are fitted with both a screw and a steam brake, which operate on the same cast-iron brake blocks, and though working from the same shaft, they can be used as required, either separately or combined.

The workmanship and finish of this locomotive is most commendable, and greatly enhances the high reputation of this old-established and well-known firm of engineers.

Vis-a-vis to the New Zealand engine is another special pical engine, almost a stranger in appearance to our English es, being distinctly American in design and of the well-known consolidation" class: and yet, while so clearly "Yankee" in any points, it has engrafted into it many excellent features of r English designs, thus making perhaps the most suitable d best adapted engine for mountain climbing over new d rough roads in new populated countries that has ever t been made in this country, and I understand that the order r these engines—which are for Vera Cruz, Mexico—was fairly d honourably secured by our neighbours of the Atlas Works, competition with the famous American Locomotive Builders; d while I congratulate Messrs. Sharp, Stewart & Co. on their ell-deserved success in securing the order, they are specially be commended for the very excellent manner in which they ave, to the minutest detail, carried out their contract, and I enture to assert that when placed side by side with American comotives, it will be seen that English work is decidedly uperior.

The engine is of one metre guage, and designed for heavy raffic on mountain railways having curves of 100 metres adius. It has the American leading track and compensating evers to secure flexibility, with steel plates, frame and attachments as usual in England. It has a steel boiler, a copper fire-box, and wrought-iron tubes. The wheel centres are cast-iron, and the tyres, axles, and crank pins are of steel. It has a link type motion, actuating the valves through rocking shafts, the valves being above the cylinders.

The smoke-box and chimney are American, the smoke-box being extended to allow room for ashes to accumulate without interfering with the draught in the lower tubes, a hopper being provided for clearing out the ashes while standing. The pump and injector are American style. The cab is roomy and comfortable, with doors giving access to the platform, and has seats for the driver and fireman. The cow-catcher and the head lamp are distinctly American. The tender has steel frames and is carried on two four-wheeled bogies, and is fitted with a screw brake.

The leading dimensions are—outside cylinders, 15¼in. dia., 18in. stroke; heating surface, 747 square feet. It has eight

coupled wheels 3ft. dia. and four bogie wheels 2ft. 2in. dia.; fixed wheel base, 11ft. 6in.; total, 17ft. 8in. Weight of engine loaded, 27¾ tons.

Tender, eight wheels 2ft. 2in. dia., on two bogies; tank, 1,400 gallons. The engine will draw on the level a load of 1,200 tons—on an incline of 1 in 100, 330 tons; on an incline of 1 in 50, 175 tons.

The engine in finish and workmanship reflects the highest possible credit on the firm of Messrs. Sharp, Stewart & Co., Limited, Manchester, who have built and exhibited it.

We next notice, what alas now is fast becoming a novelty, viz., an engine built here for a railway in the Northern portion of the Continent of Europe; and as we look at the magnificent engine, standing out so boldly and with such beautiful symmetry, we are proud to find that our local locomotive builders can, for excellence and efficiency, hold their own with ease against continental competition; and the firm of Messrs. Beyer, Peacock & Co. Limited, of Gorton, may be sincerely congratulated on the splendid high class workmanship displayed in the Main Line Express passenger engine and tender they have exhibited, it being one of an order being executed by them for the Dutch State Railway. Engines of this design, also built at the Gorton Foundry, are in daily service drawing the express trains from Flushing to Germany with remarkable regularity and qualifying success both to builders and owners.

A striking feature of this engine is the flat-topped Belpaire fire-box, so much in favour on the continent.

The leading dimensions are—Guage, 4ft. 8½in.; inside cylinders, 18in. dia., 26in. stroke; four driving wheels coupled, 7ft. dia.; two leading wheels, 4ft. dia. Boiler, 10ft. 9in. by 4ft. 2⅛in., 242 tubes. Copper fire box, 6ft. 9in. × 3ft. 5¾in., and 5ft. 3in. high at front and 4ft. high at back.

Heating surface, 1,324 square feet. Area of firegrate, 23·4 square feet.

Tender on six wheels 4ft. dia. Water tank holding 2,400 gallons. Fuel space, 142 cubic feet. Weight of loaded engine, 39 tons 0cwt. 1qr.; tender, 27 tons 10cwt. 2qrs.; total, 66 tons 10cwt. 3qrs.

This really magnificent engine and tender, as they stand out in all their simple undecorated beauty of form and design, are very impressive and imposing and elevate to a prouder standpoint, were that possible, the high-standing and eminent position of the firm who has made them.

We will next notice a very fine specimen of the new improved type of Bogie Engine now being adopted by the L. & Y. Railway Co. The engine exhibited has been made by the Vulcan Foundry Limited, Newton-le-Willows, from the designs of Mr. J. A. F. Aspinall, the Chief Mechanical Superintendent of the L. & Y. Railway Co., though in general appearance it is similar to the type of engine adopted by his predecessor, Mr. Barton Wright.

The engine, which is one of a quantity being made by the Vulcan Foundry Co. Limited, is not to be considered as made for a "show" engine, but rather as a good sample of ordinary first-class locomotive work, and as such it reflects very great credit indeed on its makers. It is designed for the heavy fast passenger traffic on the L. & Y. Railway, and no doubt both designer and maker will find complete satisfaction in its successful achievements. All the wheel centres are cast in Martin-Siemen's steel.

The Bogie has been made of the "swinging" type, rather a novelty in England, and the engine frames are made straight from end to end.

The tender is made with Ramsbottom's Patent Water Taking-up arrangements.

The leading dimensions are as follows :—Cylinders, 1ft. 5½in dia., 2ft. 2in. stroke. Four wheels coupled, 6ft. dia. Four bogie wheels, 3ft. ½in. Wheel base total, 21ft. 6in. Axles, coupling rods, &c., are steel. Boiler 10ft. 3in. by 4ft. 4in. Copper fire-box. 192 iron tubes. Heating surface, 1,031 square feet. Engine fitted with the automatic vacuum brake.

Tender: water tank holding 2,000 gallons; six wheels. 3ft. 7¾in. dia.

	t.	c.	qr.
Weight of loaded engine.....	41	17	0
,, ,, tender.....	26	15	1
Total weight.....	68	12	1

The Manchester, Sheffield and Lincolnshire Railway Co. exhibit a really handsome and highly finished Express Passenger Engine and Tender, to be used in hauling their heavy trains over the severe gradients of their main line, culminating at the east entrance of the Woodhead tunnel, at a speed of 50 miles per hour. This is a new type of main line engine, built from the designs of Mr. Thomas Parker, the Locomotive and Carriage Superintendent of the Company, and some of the leading dimensions, &c., are:—It has inside frames and inside cylinders 18in. dia., 26in. stroke. Four driving wheels (wrought-iron) coupled, 6ft. 9in. dia., 8ft. 7in. centres on the fixed wheel base; bogie, four wheels 3ft. 6in. dia., 5ft. 9in. centres; total wheel base of engine, 21ft. 9in. Boiler, 10ft. 8in. long by 4ft. 3in. dia. Fire-box, 6ft. long. Smoke box, 2ft. 9in. long. From level of rails to centre line of boiler, 7ft. 4½in.; to top of funnel, 13ft. 3in. Heating surface: fire-box, 109 square feet; tubes, 1,179 square feet; total, 1,288 square feet. Grate area, 18·85 square feet.

Tender, six wheels 3ft. 9in. dia.; wheel base, 13ft. Tank, 19ft. 2in. by 6ft. 9in. Water capacity: Tank, 2,485 gallons; well, 658 gallons; total of 3,143 gallons. With a fuel capacity of 5 tons of coal. Total wheel base of engine and tender 44ft., and total length over buffers, 53ft. 6in.

The engine is fitted with steam and the tender with screw brake. The connecting rods are of the H section, and as the whole of the materials are of the highest possible quality and the workmanship throughout is irreproachable, it will no doubt be found that in actual practice the engine will realize the high expectations of its designer and builder and maintain the well-known reputation of the locomotives of the M. S. & L. Railway.

The last engine we have to consider is one of the latest modern form of locomotive development, it being a compound tank Goods Engine, from the designs of Mr. F. W. Webb, and built by him at the L. & N. W. Railway Co.'s Crewe works.

The engine has eight wheels, of which six are driven and two leading wheels, fitted with Webb's radial axle box. The two hind pairs of wheels are coupled, and are driven by the pair of high pressure cylinders, which are 14in. dia. and 26in. stroke.

The valve gear is of the "Joy" pattern, but owing to the small size of the wheels the valve chests of the high pressure

linders have to be placed above instead of below the cylinders, in the compounds of Mr. Webb, used for passenger service.

The axle of the front pair of driving wheels has a single ntral crank, to which the piston of the low pressure cylinder coupled; this cylinder is 30in. dia. by 24in. stroke.

The tanks have a capacity of 1,400 gallons and are provided th Ramsbottom's pick-up gear for taking water whilst nning. The engine as it stands at the exhibition empty ighs 43½ tons. The following are a few of the leading nensions:—

Two high-pressure cylinders, 14in. dia., 24in. stroke. One v pressure cylinder, 30in. dia., 24in. stroke. Steel main me, 1in. thick. Steel inner frame, ¾in. thick. Length of gine framing over buffer plates, 31ft. ¼in. Width over foot ites, 8ft. 2in. Wheels all with 3in. steel tyres. Two leading ieels, 3ft. 9in. dia. Two low-pressure cylinder driving ieels, 5ft. 2½in. dia. Four high-pressure cylinder coupled iving wheels, 5ft. 2½in. dia. Total wheel base, 21ft. 6in. iler: 10ft. 1in. by 4ft. 1in. dia.; 198 brass tubes; copper e-box. Total heating surface, 1,098·85 square feet. Grate ea, 17·1 square feet. Ratio of firegrate area to heating rface, 1 to 64·26. Pressure of steam, 160lbs. per square inch.

This engine is of much interest to engineers, not only from ie fact of its being the only compound locomotive in the hibition, but as being a splendid example of Locomotive nstruction as made by a first-class railway company at their wn works and finished off exactly as if for going direct into ervice.

This engine does Mr. Webb the highest credit, and he is to e heartily congratulated that he has so persistently adhered to is compound system and determined that the actual daily ork done by his new engines should be the crucial test of their nerits; and with a fair average of steady running under all he varied conditions incident to so large a railway, it must be source of great gratification to Mr. Webb that in spite of all dverse criticism, his engines have held their own, realized the esults expected, and earned the approval of his Board of Directors.

Though not coming within the strict range of our present

notice, yet it has been a source of great pleasure that by the forethought of Mr. F. W. Webb, of Crewe, there has been exhibited a very correct model of the famous locomotive engine, "The Rocket," built by George Stephenson, and which in 1829 won the prize of £500 offered by the Manchester and Liverpool Railway Directors for the best engine for their railway; and while this engine (built within the lifetime of some of our members), in the years just preceding the Victorian era, caused such a sensation and gained so mighty a triumph, now looks so meagre and simple, we are proud to see surrounding it so varied and so magnificent a collection of locomotives which have so fully developed and so worthily succeeded in perfecting to a glorious success the future indicated by the first labour and success of the humble but now honoured locomotive, "The Rocket."

I must apologise to you that the interesting and important section of the Engineering exhibits, which I have been invited to bring before your notice this evening, cannot be more fully and worthily described, owing to the rigid and inflexible decision of our Council to restrict the length of each paper this evening to a specified time. Hence, it may appear that ample justice has not been done to the really splendid exhibits I have alluded to; but this I assure you arises simply from lack of time and not from want of will, admiration, or appreciation.

DISCUSSION.

Mr. T. Daniels complained of the scarcity of space allotted to the locomotive exhibits at the Manchester Exhibition, and expressed the opinion that the gem of the locomotives this Jubilee year was one at Newcastle Exhibition, designed by Mr. Worsdell.

On the motion of Mr. W. Lawson, seconded by Mr. T. Daniels, a vote of thanks was unanimously passed to Mr. T. Ashbury for his contribution to the records of the Association.

Mr. Ashbury suitably acknowledged the vote.

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THE MANCHESTER ASSOCIATION OF ENGINEERS
ESTABLISHED
1856.

OYAL JUBILEE EXHIBITION,

Manchester.

SHORT COMMUNICATION

BY

MR. JOHN HORSLEY

(Member of the Association,)

ON

s for the Thirlmere and Bombay Water Works,

As exhibited at Stand 672 in grounds of Machinery Section,

22nd OCTOBER, 1887,

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PIPES FOR THE THIRLMERE AND BOMBAY WATER WORKS.

The exhibits to which I have the honour to draw your ttention are samples of the large Cast-iron Pipes and ccessories manufactured by Messrs. Macfarlane, Strang and o., Limited, of the Lochburn Iron Works, Glasgow.

The Pipes, 4 feet diameter by 1⅜ inch thick (weighing over ve tons each), with the collar and tee pipe, are samples of he castings to be used in bringing the water from a reservoir, eing made in the Tansa Valley to supply the City of Bombay.

The eminent Engineer, Mr. William Clerke, M.I.C.E., of ombay, has designed and is carrying out this great under-aking. Mr. Clerke, who visited Manchester at the Meeting f the Iron and Steel Institute, explained to me many nteresting features in this important work. It is a gravitation cheme. The cast-iron pipes are to be laid above ground, as he chemical constituents of the soil are such as would speedily urn the iron pipes into graphite. Then the pipe conduit is arried over a creek, 1,500 yards wide, on an iron bridge rected for the purpose. The total quantity of cast-iron pipes equired for this conduit is 50,000 tons, almost entirely 48 inches ternal diameter, and all are included in the contract of acfarlane, Strang and Co.

The water is to be collected in the Tansa Valley, and the servoir is being formed by the erection of an enormous asonry dam across the valley, the design embracing great rength with economy. The Tansa Valley is about 50 miles stant from Bombay.

It would be easy for me to occupy the entire time at my sposal describing more particularly this gigantic undertaking, t Bombay is far away, and I think, to-night, of referring ore particularly to the cast-iron pipe of 40 inches diameter, th suitable collar, which are samples of the castings for our own anchester Corporation Water Works, Thirlmere Lake supply. need not detain you by any reference to the Parliamentary gineering and other difficulties which required to be over-

come before this scheme could be matured. But the Corporation of Manchester, and Mr. Hill, who is, perhaps, our greatest hydraulic engineer, have surmounted every difficulty, and already Macfarlane, Strang and Co. have delivered to the various railway stations along the line of Main over 10,000 tons of these large pipes. The contract with Macfarlane, Strang & Co. is for about 25,000 tons, and, as I am the representative of the Company here, I may be permitted to dwell for a short time on some of its more important details which I think may be interesting to the members of the Association of Engineers. The cast-iron pipes included in the contract are of 48 inches and 40 inches diameter. Of the larger size there are only about 700 tons, the remainder being of the dimensions of the sample exhibited. These are all being manufactured at the Lochburn Iron Works, which were some twelve years ago specially erected and furnished with all the most approved machinery for the manufacture of these large water pipes. These pipes are all cast vertically in dry sand moulds, with the socket ends downwards. It is needless to inform this meeting how the iron is melted and run into the moulds, which are sufficiently high to leave a head of metal to be afterwards cut off in the lathe, thus ensuring solidity of metal in the pipe. When the ends are being cut off, the other head of the lathe is occupied in turning the outside of the socket, on which is afterwards shrunk a wrought-iron ring, giving great strength to that part of the pipe. The pipes are now subjected to a most careful inspection. The various tests are made under the special superintendence of the inspector, who furnishes daily reports of the progress of the manufacture, the quality of the pipes, and the results of the tests. The quality of the iron used in the manufacture of the pipes is ascertained by having test bars cast at every casting of a pipe, which bars are broken by a machine specially constructed to shew the breaking weight of the bar with its ultimate deflection. The strength and solidity of the pipes are tested by internal pressure, the fluid used in the operation being oil, it being more searching than water, and also it helps to prevent corrosion of the pipes. When the pipes have satisfactorily passed all these tests, they are heated in a furnace to a temperature of about 350 degrees Fahrenheit, when they are transferred to the dipping tanks, where they take on a coating of Dr. R. Angus Smith's patent solution, which is a great preservative against corrosion in the pipes.

Dr. Smith's name will be familiar to you all as an eminent chemist of our own city, recently deceased, and this preparation which he invented, and which goes by his name, is very highly appreciated by all hydraulic engineers.

The pipes are now ready for despatch; they are then loaded in trucks and sent by railway to their destination.

I have referred to a Cast-Iron Collar suitable for these pipes, and forming part of the exhibit, and I would overlook one of the most important advances in the designing of pipes for conduit if I did not make some special reference to how these are to be used.

Ordinary waterworks' pipes are provided with socket and spigot ends, but Mr. Hill has determined to employ them to a large extent in these works. About 10,000 tons of them are to be so made—pipes with plain ends, which "butt" against each other, and are jointed with collars same as the sample exhibited. This method of jointing has seldom, if ever, been adopted in this country; but if all the advantages anticipated from its use be realised in the Thirlmere Aqueduct, it will lead to hydraulic engineers revising their practice. It may have occurred to you that these collars are narrow for two joints; but Mr. Hill has wisely I think determined to have no rope yarn in the joints of the pipes, so that there are for each joint three inches for lead on each side. The water in this conduit will not be tasted with decaying rope yarn. In this connection I would like to tell you of an invention of Mr. Nicholson, the Inspector, for running the lead into these joints. You have heard of the accidents arising from the lead being poured from the lip of a ladle into a pipe joint; if there is any dampness in the joint, the lead is thrown out with great force, resulting often in the workmen being severely, sometimes fatally, burned. Mr. Nicholson has devised a ladle to work more economically than the old system, and besides avoiding all risk of accidents to workmen. It is a ladle with a valve at the bottom. It is placed above the joints. A workman at some distance pulls the valve handle, and in a few seconds the joint is made. For the collar joints there are two valves in the bottom of the ladle, so that the joints are made at the same time. The advantages of this new method must be patent to all.

I have tried in these few sentences to give you some information of general interest on the exhibits of Macfarlane,

Strang & Co., Limited, and concerning the large contracts in which they are engaged. Their productions of cast-iron pipes amount to about 1,000 tons per week. Sometimes I think there are no greater public benefactors than pipe founders, and I never more realised this than when I listened to the peroration of our worthy President, Mr. Alderman Bailey, in his address to this Institute, in July last, at the exhibition. Mr. Bailey, in recounting the triumphs of civilisation, and especially the noble functions of the engineer, said :—" Plague and pestilence and " famine, the ancient enemies of mankind, shrivel up at the " approach of the engineer. Waterworks introduced by English " engineers have nearly annihilated the yellow fever in our days " in the cities of the South American Coast."

All honour to the men who engage in these noble enterprises; all honour to the men who are giving us a new and plentiful supply of pure water which will go far to keep our city in the front rank of civilised communities.

I thank the Council of this Association for the opportunity they have given me of bringing this subject before your notice, and I thank the members present for their kind attention to these few remarks.

DISCUSSION.

Mr. Horsley, replying to several questions, said that he had not the Thirlmere specification by him, but he might say that the pipes were about 1¾in. thick, and were tested to 300lb. pressure. As to the method of caulking, it was that which the makers were compelled to carry out by the engineer, and as to its efficiency or not he was unprepared to say. The cast-iron rings were used where the pipes were cast without sockets, where they butted up against each other the cast-iron ring made the joint. The wrought-iron rings were shrunk on the ends of the pipes which had a socket at one end and a spigot at the other.

On the motion of Mr. W. Lawson, seconded by Mr. T. Daniels, a vote of thanks was unanimously passed to Mr. J. Horsley for his contribution to the records of the Association.

Mr. Horsley suitably acknowledged the vote.

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1856.

ROYAL JUBILEE EXHIBITION,

Manchester.

SHORT COMMUNICATION

BY

MR. JOSEPH INGLEBY,

(Member of the Association,)

ON

KNOP'S TURBINE,

As exhibited at Stand 404 Machinery Section.

22nd OCTOBER, 1887,

AT THE GRAND HOTEL, MANCHESTER,

R. THOS. ASHBURY, C.E., Past-President,

IN THE CHAIR.

MANCHESTER:
HERALD & WALKER, PRINTERS, BACK POOL FOLD, CHAPEL WALKS.
1887.

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15, Raglan Street, Hulme.

KNOP'S TURBINE.

ure, as a small contribution to this evening's work, to
ur attention to a modest exhibit of a *Single Turbine*,
ou will find on Stand No. 404, being a water-wheel
ted on Knop's principle, and which presents a few
worthy, I believe, of notice.

ugh only quite recently introduced into this country
Henry Simon, this turbine is very well known on the
t, where many hundreds are at work, and where wheels
construction bear a singularly good reputation for
under almost all the varying conditions of fall and
of water, but more particularly for specially ad-
ous results where the falls are low, and both fall and
of water subject to very great variation.

nces exist where the fall is decreased in winter by floods,
the other hand the quantity of water reduced in summer
ght to fully 75 per cent. below the normal point, and
under such extremes Knop's Turbine is giving an
dentedly high average useful effect.

s the fact of such cases continually coming under notice
one hand, combined with an equally repeated experience
res under similar conditions in this country, which led
ntroduction of this wheel.

are a large number of different makes of American
s which have been energetically pushed and numerously
in this country, but which often refuse to justify here
wing accounts of their excellence which accompanied
om the land of their birth. Constructed for a certain
ormal fall and quantity of water, they give excellent
in the States, where in most cases this generally high
this certain quantity of water can be relied upon with
all variation all the year round. Here, on the other
he great characteristic of our water-power is *variable*-
good stream and fair fall for three months of the year
to a trickling rivulet in summer, or swollen to a heavy
ith almost constant backwater, in winter. Then again,

the degree of variation and the nature of the same is different, often widely different, in cases where the normal quantity of water and average fall is the same.

The proprietor, plagued with a stream very subject to drought, who orders from a catalogue—column A, fall; column B, quantity of water in feet per second; column C, effective horse-power, &c.—a turbine wheel made in standard sizes (30in., 36in., 42in., 48in., &c.), like garden lawn-mowers in a hardware shop, and who happens to *blunder* into selecting a wheel of the "Re-action" type, soon finds to his cost that his wheel gives a very low percentage of efficiency at part-gate, and below a certain quantity of water cannot be worked at all. His neighbour selects therefore a "Girard" Turbine; but as the main peculiarity of his stream is frequent flood at the head and prolonged backwater in the tail-race, his "Girard" wheel is drowned and thereby loses much effect unless fixed above the highest tail-race level and a portion of the fall sacrificed. I am perhaps presumptious in repeating at length considerations like these, already well known to many, but it is done to lead up to one of the "points" which I wish to make, and which as engineers I am sure you will appreciate.

The makers of turbine wheels must appreciate this peculiarity of water power, *must* recognise the necessity of carefully considering the conditions under which each wheel must work, and must make *each* wheel *specially* to suit those conditions, instead of using a stereotyped size and make, regardless of the peculiarities which vitally affect the success of the wheel.

The accompanying drawing shews the main features of the Turbine.

The special feature of it is that it is intended to combine the good points of the veteran "Jonval" and "Girard" wheels without their defects, so that with a useful effect of 75 per cent. under normal conditions it has been proved in many cases not to give less than 70 per cent. where on the one hand the tail-water rises and immerses the turbine so as to reduce the fall by two-thirds, and on the other hand still 70 per cent. of useful effect when the quantity of water is reduced to quarter-gate, or even lower in some instances. The chief factor in this result is the combined shape of the vanes or buckets in the guide wheel and turbine wheel by which the impulse or velocity of

the water is used to the full extent instead of relying on the dead weight of the water. On this account it suits *low* falls down to 3 or 4 feet, and especially in places where such a fall renders the utilisation of the impulse of the head stream desirable.

To carry out this principle the regulating slide or apparatus is so constructed that the angle of the water entering the turbine *is never altered*; to meet varying quantities of water the *number* of buckets in use is varied by this slide, so that those remaining in use are *always full.*

The improved shape of the bucket, that is the combined curve of the vanes which lead the water on to the revolving wheel, and of those in the wheel, which thus receive the impulse, is varied and determined by Knop's principle to suit the varying conditions of each application. On this account the vanes are made of wrought-iron, curved as required, and then inserted by moulding machinery and cast into the wheels. They are so curved that the water flows with the least possible resistance through the guides, and is delivered on to the wheels with the least possible shock, whilst filling the *entire space in each bucket*, and *escaping from it* at the lowest velocity.

In many other turbines these vanes in the guide wheel are made movable on a pivot, by mechanism from the top, but in such wheels, with low water, the angle at which the water enters the wheel is utterly changed, the wheel buckets are all *only partially filled*, and a great loss of effect, as compared with full water, ensues.

The regulating or butterfly slide (see the model) will show how the *number* of buckets is increased or decreased in this wheel, so that none of the buckets in use are ever partially but always *completely filled.* This and the unalterable angle at which the water enters the wheel are two most important features. The ventilation of the wheel can be effected from one of the guide buckets, or through the regulating slide.

The wheel on its shaft revolves in, and is carried by a top step bearing, shewn in the drawing, fully accessible for cleaning and oiling, and specially constructed of steel and phosphor bronze to stand the wear and tear. You will notice that this bearing only supports the weight of the shaft, the revolving wheel and the quantity of water passing through the buckets of

the revolving wheel at any given moment; the main weight of the water above the wheel is carried by the guide wheel and its flanges, resting on the girders in the bottom of the flume.

Another point of value in this country, where the track of the lowland streams flowing through our meadows is so often marked by a double fringe of alder, elm, or willow, shedding their leaves and branches in the water, is the fact that the wheel is not easy to choke and is easy to clean out.

It is also of some interest to know that, on all-fours with the practice of so many of our large well-known firms, accuracy and reliability are insured before delivery by test and experiment. Although not usually done in this branch, the works in question have a complete turbine testing apparatus with gauged tank, turbine pit, and dynamometers for testing the duty performed by the wheels. The results obtained by the wheels in use in this country have so far justified the claim that the points I have drawn attention to are important, and the improvements real.

DISCUSSION.

Mr. Rea said he could not take the same enthusiastic view of the efficiency of the turbine as Mr. Ingleby, and stated as his emphatic opinion that it was impossible to take the full efficiency out of water by the simple process of action; and with reference to the machine before them, he thought that in actual practice he could reduce its efficiency to 35 per cent.

Mr. Ingleby distinctly denied that Mr. Rea could reduce the efficiency of the turbine to the figure stated by him. He (Mr. Ingleby) made his assertion on the basis of acknowledged facts, and was prepared to substantiate them at a more favourable opportunity.

On the motion of Mr. W. Lawson, seconded by Mr. T. Daniel, a vote of thanks was unanimously passed to Mr. J. Ingleby for his contribution to the records of the Association.

Mr. Ingleby suitably acknowledged the vote.

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THE MANCHESTER ASSOCIATION OF ENGINEERS.
ESTABLISHED
1856.

ROYAL JUBILEE EXHIBITION,

Manchester.

SHORT COMMUNICATIONS

BY

MR. WM. SCHROLLER,

(Member of the Association.)

ON

Ammonia Still, and Process of Manufacturing Sulphate of Ammonia,

AND

Coke Oven and Ammonia Still,

As exhibited at Stand 718 Chemical Section.

22nd OCTOBER, 1887,

AT THE GRAND HOTEL, MANCHESTER,

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15, Raglan Street, Hulme.

AMMONIA STILL, AND PROCESS OF IANUFACTURING SULPHATE OF AMMONIA.

The fall in the commercial value of gas works residual of late ,rs has also adversely influenced the Ammonia Industry, ich is an important one in this country. In a great measure s evil could, no doubt, be remedied if the British farmer ıld be got to see the importance of a manure (Sulphate of ımonia) which is produced in large quantities in his own ıntry.

One of the most successful plants for the manufacture of lphate, as well as of Liquid Ammonia, in this country and road, is an improvement of Mr. Henry Simon, Manchester, on Dr. Grüneberg's plant, which has been mainly brought bear upon the construction of the Still. The results ained show marked improvements on Dr. Grüneberg's ginal construction. The Still is worked entirely by live am. The top part of it, which is intended for the distillation the "free" ammonia salts of the liquor, has not been ered. The improvement effected is in the bottom part of the ll, which deals with the "fixed" salts by treatment with ıe. The liquor is made to flow down a stepped cone arrangeıt, whereby it offers a gradually increasing surface to the am. Thus the most intimate contact is secured between am and liquor.

The process of distillation is a continuous one, viz:—The s liquor is continuously run into the Still, the ammonia gas continuously discharged, and the waste water (in a harmless ıte as far as sanitary considerations go) is continuously and tomatically overflowing, by means of a hydraulic seal arrangeent of simple construction. The Stills are made of various pacities, the smallest size made being for working off about t tons of ammoniacal liquor per 24 hours.

Of course, the plant can be arranged in various different ways to suit special requirements, but as a rule the process of manufacture is as follows :—

The gas liquor is pumped into an overhead tank, placed high enough, so that in gravitating down it may overcome the pressure inside the Still. The liquor has to pass a heater, heated by waste gases from the saturator, and it enters the Still at about 180 degrees Fah. The free ammonia is first driven off in the upper part of the Still, then the liquor is treated with milk of lime, in order to release the fixed ammonia. The ammonia gas (together with the CO_2 and SH_2) is carried from the Still by means of a lead pipe to the saturator, in which it meets with sulphuric acid. The ammonia is thus fixed, and the SH_2 and CO_2 gases are passed through the before-mentioned heater into an oxide purifier. As a rule, these gases are dried in some suitable condensing arrangement before sending them into the purifier.

In a few hours after the ammonia has commenced to come over into the saturator, the sulphate begins to form and falls to the bottom. It is then fished out by perforated ladles, and, after draining it for some time, it is thrown on to the drying stage, after which the salt is ready for sale.

A beautiful white sulphate, containing about 25 °/₀ of NH_3, can be made by using sulphuric acid made from spent oxide.

COKE OVEN AND AMMONIA STILL.

On the same stand (No. 718, Chemical Section) Mr. H. Simon, of Manchester, also exhibits a model of his system of Coke Ovens, and as coking and manufacturing ammonium salts are allied industries, I propose to describe *both* these exhibits: in fact the Coke Oven was only inadvertently omitted from the notice paper to this Association.

The Coke Oven.

This system of ovens is well known now in this country, having been in use several years, and works very successfully in making metallurgic coke, tar, and ammoniacal liquor at the same time. The model at the Exhibition illustrates also the recuperator or arrangement for heating the air necessary for combustion to a very high temperature by means of waste gases. The model shows that the oven itself consists of a long narrow chamber (25ft. by 7ft. by 20in.) constructed of fire bricks, and the sides of which chamber are surrounded by longitudinal flues which the heating gases are forced to traverse in a zig-zag fashion. There is also a heating flue underneath the sole of each oven. There is no combustion going on inside the oven or coking chamber, as the heat is applied externally to each oven, and air is carefully excluded from these chambers where the coking process is going on. The gases which are evolved during the carbonisation are taken away from the ovens by means of exhausters, pressed through the apparatus employed in abstracting the tar, ammonia, and benzol, and thus deprived of these constituents the gas is returned to the oven flues, mixed with hot air and ignited, and thus made to serve as fuel in the process of making coke. The ovens themselves of course consume a great amount of heat from the combustion gases, but still enough heat is left in the waste gases to be enabled to cause the air required for combustion to be heated to about 1,000 degrees Fahrenheit. This interchange of temperature is effected in a series of air flues arranged outside the ovens. These air flues are surrounded by the flues in which the waste gases are

travelling on their way to the chimney. This recuperator of heat (as it is called) is continuous in action and self-acting, and as it is arranged outside the ovens and free from the brickwork of the same, the solidity of the ovens and flues is preserved and losses of gas and bye-products effectually prevented.

The temperatures in the flues vary from 2000 to 2850 deg. Fah.

As a check to the pyrometrical tests made, it may be mentioned that copper may be melted in the top-flue and iron in the flue directly underneath the sole of the oven. These bottom flues are lined with best silica bricks, containing nearly 96 per cent. of pure silica, and this enables these ovens to stand the high temperatures employed, very well.

The excellent qualities of coke obtained, as well as of the bye-products recovered (samples may be also inspected at the Exhibition), are due:—

(1) To the very high temperatures employed.

(2) To the existence of the conditions necessary for a true destructive distillation of the coal.

(3) To the mode of application of these high temperatures.

The yield of coke varies of course according to geological position of each colliery where these ovens are at work: it is about 77 per cent. in County Durham, about 69 per cent. in Lancashire, and about 62 per cent. in Staffordshire. In fact nearly all the carbon contained in the coal is converted into good metallurgic coke. The time of carbonisation in working off a charge is 48 to 50 hours. As to ammonia recovered, this again varies with the kind of coal employed. Expressed as sulphate of ammonia, the yield per ton of coal carbonised is 1 to 1¼ per cent. with the North Country coal and about 1½ per cent. in the case of Staffordshire coal.

The quantitative yield of tar varies from about 3 to 6 per cent., while the quality of the same is equal to any other high temperature tar, the specific gravity being about 1·1 on the average.

DISCUSSION.

Mr. Joseph Nasmith said he had had some experience in the processes referred to by Mr. Schroller, and he was able to say that the Simon-Carvé process was undoubtedly the one which secured the best results. Processes which had from time to time been used for extracting the by-products from coke manufactured at low temperatures had, he believed, proved to be complete failures, and this statement might perhaps come with all the more force inasmuch as it was well known that, some time ago, he was considerably in favour of these low temperatures of distillation. His experience was that when they distilled coal at a low temperature, and took off the gas at a low temperature, so far as the by-products were concerned they did not get anything of real value. The Simon-Carvé process had undoubtedly produced the highest class tars; that was to say, of the highest commercial value.

Mr. Schroller, in replying to the discussion, remarked that notwithstanding the unfavourable report which Sir Lowthian Bell had made with regard to the Simon-Carvé process, there were thousands of these furnaces being put annually into use on the Continent. In Lancashire and Staffordshire they were coming gradually into use, and it was principally in Durham, were coke was so plentiful, that they were not making much headway. Where the economical production of good coke was a necessity these furnaces would come gradually into use.

On the motion of Mr. W. Lawson, seconded by Mr. T. Daniels, a vote of thanks was unanimously passed to Mr. W. Schroller for his contributions to the records of the Association.

Mr. Schroller suitably acknowledged the vote.

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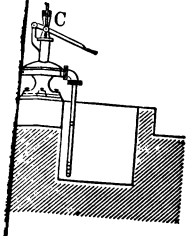

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THE MANCHESTER ASSOCIATION OF ENGINEERS
ESTABLISHED
1856.

ROYAL JUBILEE EXHIBITION,

Manchester.

SHORT COMMUNICATION

BY

MR. R. SUGDEN,

(Member of the Association,)

ON

THE FOUR LARGE STEAM ENGINES,

Machinery Section,

22nd OCTOBER, 1887,

AT THE GRAND HOTEL, MANCHESTER,

MR. THOS. ASHBURY, C.E., Past-President,

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THE FOUR ENGINES TURNING MACHINERY AT THE MANCHESTER EXHIBITION.

I have to apologise for the very crude and incomplete condition of the paper I have to read before you this evening. Two weeks ago I had no idea I should be called upon to take part in this or any other meeting in the immediate future. The time at my disposal was much too short to prepare a paper on a subject of such importance, and I think you will agree with me that the subject is a very delicate one to handle, in consequence of the varied interests present, and the probability of my remarks differing more or less from the opinion of my auditors. However, I simply give an opinion from a casual visit. Some of us are sure to hold contrary opinions. It is impossible to construct a piece of machinery which will suit everyones' idea and taste. My idea of an engine is to attain to the highest possible degree of perfection with the simplest, and at the same time, the most durable arrangement of working parts; a condition of things we don't always find in real practice. I have noticed remarkable cases of attempted imitation of mechanism, which have been entirely void of useful result; being simply an imitation of the principle. There appears to be a tendency on the part of our engine builders to increase the complication of working parts, for the attainment of desired results, which may be achieved in a simpler and neater manner. Such complications often prove to be a great nuisance and source of expense to the owner, as well as worry to the attendant, which consideration ought to be strongly kept in view in designing any machine, for whatever purpose it is intended. It is a bad sign when the builder of an engine is seen frequently visiting, along with his men, an establishment to which he has supplied an engine. The simpler and more comprehensive mechanism that can be arranged, the better it will command a market. To make everything as nearly automatic as possible ought to be the aim of all engineers,

since the less attention required, the more cheerfully and consequently, the more efficiently it will be done. Quality ought to be, and is the most essential requisition. The more convenient and pleasant a man's duty is made the more value his employer will get out of him. All right-minded men are finding that their interests are common with their employers, and, as a consequence, endeavour with various degrees of success to advance their employers' interests, while the latter are meeting them in many ways, especially in procuring efficient machinery.

There is much to be considered in the choice of an engine, and we have a fair selection at the Royal Jubilee Exhibition for most purposes. A finer collection of engineering skill I think it would be difficult to find, though there is not a very large variety. The four before our notice have all circular valves only differing in detail of arrangement, and the possessor of any one of them may congratulate himself that he owns a really splendid engine. Of course results are what we want, and for the results of these individual engines we shall have to wait, there being no means of testing them in their present position; but we may form from our experience of engines generally a probable result of each of them; each of which justly claim some special advantage. The one claiming the greatest novelty of design and appearance is the pair of Wheelock engines, made by Messrs. D. Adamson and Co., and for which I confess to having an inclination, since they suit my idea for neatness and effect. The beauty of finish is by no means a defect. It is a pleasure to watch them work, their action being very smooth and quiet. They are compound with 16in. high-pressure and 28in. low-pressure cylinders, 3ft. stroke, and indicate at present, without condenser, about 120 horse power. They are fitted with condensing apparatus, but the air-pump bucket is left off, there being no water for condensing purposes provided at the Exhibition. The bed is of the trunk girder type, crank shaft brasses are adjustable back and front, with adjusting screws through the cover. Both the high and low-pressure cylinders are fitted with circular steam and exhaust valves, and have adjustment for wear, a very important advantage; there is only one steam port at each end of the cylinders, and that as short as possible. The valve motion

is exceedingly simple and effective, and as neat an arrangement as is possible to imagine, it also being very light to drive; the governor has perfect control over the valves, there being not the slightest pluck apparent on them. The construction of the valves and valve spindles enable them to work without stuffing, and, as a proof of their durability, it may be mentioned that there is an engine at work at Messrs. D. Adamson & Co's works which has been at work for many years, and is still in efficient working order, the valve spindles being perfectly steam-tight. All the valves are placed on the underside of the cylinders, giving free delivery of water, an important advantage where priming takes place. The governor arrangement has also a very ingenious advantage applied in the event of racing, or governor driving breaking down, viz:—the governor reverses the trippers and effectually closes the valves and stops the engine. The engine is constructed throughout with a view to minimise attendance. The cylinders are fittted with continuous lubricators, but the crank-shaft and crank-pins are not; these are little points which ought not to be neglected; they appear very insignificant compared to the construction of the engine, but how little will upset the whole fabric, practice often shows. Messrs. D. Adamson & Co. have kindly supplied me with the illustrations and indicator diagram of the engine at work at the Exhibition. It would have been interesting to have seen a speed recorder diagram, but there is not one attached to the engine. As a testimonial, however, to the governing power of the engine, the attendant recounted to me an incident which occured a few days previous to my visit. It seemed that the two main driving-belts on the second motion shaft fouled and came down, and the engine immediately recovered itself, though running with scarcely any load. I consider this engine to embrace beauty of finish, neatness of construction, efficiency and good workmanship; the beauty of finish is worthy of notice.

The engine supplied by Messrs. J. and E. Wood is one of a pair of Corliss engines, being the high-pressure side of a compound engine, similar to a pair supplied to the Mather Lane Spinning Company, and which are giving great satisfaction. The cylinder is 25in. dia., and, as may be seen by the indicator and recorder diagrams, the engine is doing very good work.

These engines also have the advantage of having all the parts on the underside of the cylinder, and a very simple and durable arrangement of trip gear to the valves; the cross-head, however, might be made with larger wearing surfaces. The crank looks very light and suggests loose pins. The engine on the whole is a very noble looking piece of machinery, and one capable of giving very good results, and reflects very great credit upon the builders. It is automatically lubricated throughout. I regret I have been unable to get more details of this engine.

The single Corliss Engine by Messrs. Hick, Hargreaves & Co. is a very pretty engine, on the style of which a great number have been built and have given satisfaction. Some of these are very large, notably those sent out to India, which were named a White Elephant. I recently heard, however, from a gentleman who had just returned from that country, that they are working much better than was anticipated. But we need not go to India for examples of these engines, as there are many at work in this country, some of which I have to do with at the present time, I may say the engine and recorder diagrams do not come out so well by far as those with which I am acquainted, one of which, with the aid of Knowles' supplementary governor, is giving perfect governing and far better indicator diagrams. I believe the cause of this failing in the Exhibition is mainly due to the fact that they have a reducing valve on the steam pipe which they have adopted in consequence of the engine being very lightly loaded. This engine is not so simple as the previous ones mentioned and requires more skilful attendance. The bed is of the Trunk Girder type, the cylinder steam jacketted and fitted with Corliss and Inglis improved valve gear, the cross head slides have very large wearing surfaces, the connecting rod is very light and looks flimsy. The engine is fitted with Knowles' supplementary governor, which is a very good regulator. The barring engine is a very massive piece of mechanism, and works very satisfactorily: the engine is automatically lubricated throughout.

Messrs. Musgrave & Co. exhibit a very powerful and massive pair of engines, being a Compound Corliss Engine fitted with their improved valve gear and trip motion, which appears very com-

plicated, but at the same time very durable. These engines are giving every satisfaction where working. There are a number in this neighbourhood, and they are well liked by the engine attendants, which fact always speaks well for an engine. Engine attendants as a rule are always ready to complain and find fault wherever there is the slightest excuse; if they speak well of their engine, it must be a satisfactory job and a profitable investment for the owner. The engine attendant's comfort is the master's gain. The valve gear is much heavier than necessary for the duty it has to perform and occupies too much space. I may say that the simplest and the best engine I have had under my care was a Compound Horizontal, fitted with slide valves with back slide cut off, controlled by the improved trip gear, which gave very good running. I have been unable to get any details of these engines at work at the Exhibition. The automatic regulating gear has been removed I believe with the object of applying Wilby's regulator, a very neat and effective arrangement just placed before the public. Messrs. Musgrave & Co. also shew their Automatic Barring Engine, a necessary adjunct to large rope driving engines. These engines are lubricated automatically throughout.

On the motion of Mr. W. Lawson, seconded by Mr. T. Daniels, a vote of thanks was unanimously passed to Mr. R. Sugden for his contribution to the records of the Association.

Mr. Sugden suitably acknowledged the vote.

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THE
DERN COTTON CARDING ENGINE.

A PAPER

READ BY

R. JOSEPH NASMITH,

(Member of the Association,)

ON 12TH NOVEMBER, 1887,

AT THE GRAND HOTEL, MANCHESTER,

derman W. H. BAILEY, J.P., President,

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THE
MODERN COTTON CARDING ENGINE.

The process of carding fibrous materials must be of great ntiquity, and it would not be difficult to find ample confirmation f this in the works of the old writers. It is not, however, with ıe antiquity of the subject that this paper is intended to deal. t will be quite clear on a little reflection that the ancient arding process was more likely to be a combing action, as the lea underlying the treatment of the fibre at this stage was that f the necessity for straightening it before proceeding with the pinning. That this is the true state of the case can be proved y ample evidence, and it is therefore not necessary to go into ıe matter further. With the advent of the improved carding ıachine first invented by Daniel Bourne in 1748, and later in ıe same year by Lewis Paul, the combing was subordinated to cleaning action, and it is on this basis that all the machines f this century have been constructed. If any member desires o study the evolution of the carding machine for cotton from he crude machine referred to, he cannot do better than go into he matter with Mr. Evan Leigh's work before him. It may, ıowever, be pointed out that before the death of Sir Richard Arkwright the whole of the essential parts of the machine as at resent constructed were devised. Thus, in Lewis Paul's patent, he use of flat bars covered with wire clothing was specified, as, n the earlier patent of Daniel Bourne, the use of a revolving wire-overed cylinder had been described. To these two essentials vere added by Arkwright the doffer and the doffer comb, and it s thus seen that almost the whole of subsequent inventors have ealt with the improvement and development of the details of he machine. It may be said at the outset that the object of his paper is to look at the machine from a mechanical point of iew, and that, except incidentally, it is not intended to treat from the spinner's side.

When cotton is brought to the carding engine, it has been y means of the preparatory processes, cleaned and opened,

although it has not been thoroughly freed from all impurities. The proportion of the latter, however, speaking comparatively, is not large, and with the improvements gradually taking place in the scutching machine is yearly growing less. Owing to the method in which the material has been dealt with in the earlier stages, it is not in a fit condition to be sent to the machines for drawing and spinning, there being in the lap a good many short fibres and "nep" or knotted pieces, the effective removal of which is absolutely essential to the production of a good yarn. Thus the operation resolves itself into a cleansing process, alike by the removal of any remaining "motes," short fibre or "nep," and the primary condition of doing this is that nothing but these impurities and defective substances shall be removed. That machine best fulfils the object of the spinner which removes the whole of the impurities referred to, with the least admixture of fibres which could be advantageously used in spinning. Of course this is elementary, but at the same time, it is absolutely necessary to bear it in mind in properly estimating the value of various machines or duly appreciating the mechanical contrivances designed to effect the object.

In order to clear the ground it may be as well to say at once that the only type of machine which will be dealt with in this paper is the one which at present is being universally adopted, and known as the revolving flat card. The older types of machine known as the roller and clearer and self stripper are both possessed of much mechanical interest, but the limits of time prevent their being referred to. Beside this the construction of the revolving flat card involves a nice mechanical problem which is worth a special consideration, and the solution of which has given rise to a number of ingenious inventions. The general appearance of the machine is well shown in Fig. 1, and a brief description of this drawing will fairly convey an accurate notion of the method of construction. Revolving on the shaft, shown in the centre of the machine, is a cylinder, usually 50 inches diameter and 37 to 40 inches wide, the entire surface of which is covered with wire clothing applied in a manner to be hereafter described. The cylinder revolves in bearings bolted to the frame, which also sustains a semicircular frame K, acting either as a course for the traverse of the flats or in some way or other

carrying it. The cotton, which is formed on the scutching machine into a roll or "lap" 40 inches wide, is shown at A, the lap being fed by rollers at a regular speed. Between the cylinder and the lap, at the point B, is a roller 9 or 10 inches diameter, of the same width as the former, and covered with wire clothing of a special kind. This roller is called the "taker-in" or "licker-in," and takes the cotton from the end of the lap, delivering it to the wire clothing on the cylinder, the teeth of the two being so set as to enable this to be easily effected. The cylinder having taken the cotton carries it round and is finally stripped by another roller E, called the doffer, which is also covered with a wire surface, and is about 24 inches diameter. Adjoining the outer surface of the doffer is a small blade or comb, extending across the face of the former, and having a rapid oscillating movement. This comb strips the fleece of cotton from the doffer in a continuous sheet, which is collected into a round strand by passing it through a trumpet-shaped orifice. The collected fibre is called the "sliver," and after passing through two calender rollers which slightly compress it, it is carried upward to the coiler H, consisting of a short tube angularly placed on the upper part of a plate revolved by suitable gearing. The tube at its upper extremity is in the centre of the coiler but delivers the sliver, which passes through it, at a point near the periphery of the tube plate. In this way the sliver is placed in circular layers in the can G, which, when full, is transferred to the drawing machine. During the passage of the cotton from the licker-in to the doffer, it is carried under the chain of flats D, those being borne as illustrated. Each of these flats has its underside covered with wire clothing, and the whole of them travel in the same direction as the cylinder but at a very slow rate. It will be noticed at a glance that as the flats travel onward they pass round the carrier pulleys shown, and are turned with the wire surfaces upward. When this happens they are stripped by an oscillating comb, and afterwards brushed out by the revolving brush shown at the left hand side of Fig. 1.

The action of this mechanism is as follows:—The licker-in takes the cotton from the lap in a downward direction and carries it to the main cylinder, the surface velocity of which is

about 2,000 feet per minute. The licker-in travels at about half that rate, and as the wires of the two are almost in contact it will be seen that the superior speed of the cylinder will strip the cotton from the licker-in. In like manner the cotton is carried to the point of contact with the doffer, the latter revolving in the reverse direction to the cylinder, the teeth of the two thus opposing each other, and as the doffer only revolves at a very slow rate, the greater speed of the cylinder transfers the carded cotton with a combing action to the doffer, from whence it is removed by the oscillating comb as described. The flats vary in number, in some cases there being only 89, and in others 110. The teeth of the wire in the flats are set so as to face the approaching wire teeth on the cylinder, being nearer the cylinder at the front of the flat than at the back, in order to card the fibre which is thrown up by the revolution of the cylinder, and catch the short fibres and nep which are being carried forward by it. The flats only move about an inch a minute so that their wire surface will easily take up the loose fibres. The points of the wires on the cylinder and flats are set as close as possible together without touching. When the flat reaches the comb its wires are cleansed or "stripped," the strippings falling on to the polished plates covering the doffer and cylinder.

Having thus briefly indicated the general construction of the machine and its action, one or two points arising may be dealt with. To begin with, the question of the laying of the various fibres of the cotton parallel may be glanced at. While it is generally believed that the objects of carding include that of straightening and laying the fibres parallel, it would be very difficult to establish this proposition from the facts of the case. Indeed, it may very well be doubted whether any mode of operation could be devised by which the short fibre of cotton could be continuously combed or carded so that the several fibres should be parallel. A close examination of the sliver while in the sheet form will show that, so far from this being the case, the fibres are crossed in all directions, and it is at least doubtful whether this is not the case to a greater degree than exists in the lap. The subsequent drawing operation largely rectifies this defect, but that it exists is certain. The counterpoise to this disadvantage is found in the fact of the large production, which

is possible with a machine of this class in contrast with a machine which actually combs and lays in parallel lines the cotton fibres. Other points, such as the shape of the wire points, and the renewal of these by grinding will be dealt with hereafter, but in the meantime the question which is the *crux* of the problem remains to be treated.

It will be quite clear that, inasmuch as the function of the flats is to remove by means of the wires attached to them the short fibre and nep, the more accurately the distance between the wire clothing on them and the cylinder is preserved, the better will be the effect produced. Now, in order to attain this object it is necessary that the flats should be specially constructed and carried. A reference to Fig. 4 will show the construction of the flat, which is so finished (as will afterwards be explained) that the faces upon which it travels are parallel with the face upon which the wire is fixed. Thus, if the flat is borne upon a surface which is concentric with the surface of the cylinder, but so far from the centre of the latter as to compensate for the length of the wire on both, and provided that the two wire surfaces are accurately and evenly ground, it will be clear that over the whole of the surface there will be the same distance between the points of the wires. This is the condition which is absolutely the best for carding, but its constant maintenance is the problem. The flat course may be either formed on, or attached to, the frame K (Fig. 1) and in either case is technically termed the "bend." This phrase is often very indifferently used, and is sometimes applied to the framing K when the latter is acting as a course for the flats, and sometimes to the surface attached to or borne by it for the same purpose. It ought however to be insisted on, for the sake of clearness and definiteness, that the phrase "bend" should only be applied to that portion of the mechanism upon which the flats actually travel. Now let it be assumed that a machine is in condition for starting for the first time, that the surface of the flat end upon which it travels is set back from the flat wire surface inch, and that the wire projects ½inch beyond the cylinder surface, we here get the necessity for a circle with a radius of 6 inches. It is, of course, perfectly easy to form a track on the edge of the frame K, which should be accurately machined

so as to be quite concentric and of the radius required, in which case the required distance between the two wire surfaces could be perfectly established. But, during the operation of the card, the wire points become blunted and no longer deal with the cotton as efficiently as they ought. This necessitates their re-sharpening by grinding, which involves a reduction of the size of the circle described by the points of the cylinder wire, and an enlargement of that described by the covering of the flats. As has been pointed out it is better that the two wire surfaces should approach one another as closely as possible without touching, the most effective results being obtained in this way, and it therefore becomes necessary to find some method of lowering the flats in order to re-establish these conditions. This is precisely the difficulty which has to be overcome. It is perfectly clear that any flat course formed on the frame K cannot be so adjusted, and it is essential that some other adjustable surface sustained by K shall be found. Now if for a minute or two the work to be done is considered it will be seen that there is a very difficult problem here. If a circle is struck 51 inches in diameter, and at the same time a second circle 52 inches in diameter is described, from the same centre, some idea can be obtained of the actual conditions of the case. Suppose now that the circle 51 inches diameter is reduced to 50¼ inches (this representing the extreme variation in size arising from grinding), it will be at once observed that the dropping of the 52 inch circle in a radial line will be followed by the destruction of its concentricity with the other. In the case thus supposed the smaller circle represents the surface of the wire on the cylinder, while the larger one represents that of the ring upon which the end of the flats traverse. Now, while the former is reduced with ease by grinding, the latter is not so easily reduced, and the action of moving it nearer the centre, without its reduction, simply means that its centre is moved to the same extent, while the centre of the ground surface remains constant. In other words the concentricity of the two circles is destroyed. Now, as the concentricity of the flat course with the cylinder is absolutely essential, in order to get that close approach over the whole of the wire surfaces which has been shown to be necessary, it follows that its destruction implies ineffective and bad carding.

How then is this object to be achieved? How is it possible to find a surface upon which the flats shall be firmly sustained and carried, which can be lowered in a radial direction and maintain its concentric form? The answer to this query is found in the various contrivances to which your attention is now called.

The arc occupied by the flats in their traverse varies from 120 to 150 degrees, speaking roughly, so that in some way or other a flat course of that length, capable of adjustment, requires to be provided. By far the most common method of providing this is to fasten to the side of the machine at the upper edge of the frame K a flat plate with its upper edge forming a segment of the circle required. The shape of this plate so far as its depth is concerned is so arranged that it can be sprung or compressed into a smaller circle with the minimum amount of difficulty and strain. This is what is known as a flexible bend and is in wider use than any other form. It is attached to the frame side by bolts, slots being formed in the bend casting at each end through which the bolts pass. It will be seen that the slots allow of a considerable range of movement in the bend, which is made use of in setting it after the wire has been ground. The setting is effected by springing the bend by means of screws until a circle is formed equal to that required to enable the wire surface of the flats to be concentric with the wire surface of the cylinder. As a matter of fact the setting is done by the carder by sound and by the use of a gauge, the combination of which permits him to ascertain fairly accurately that the flats are in a good working position. When the bend is set, it is locked against the frame by the bolts, and stops, which are placed midway between the points of support, are brought up to the under edge of the bend. The object of these is to uphold the bend so as to avoid deflection from the weight of the flats. The flexible bend has many advocates and many opponents, all of whom have reasonable ground for their contentions. On the one hand it is contended that by this bend, not only can the diminished circle arising from grinding be provided for, but also the possible change of the centre of the circle which occurs from the wear in the shaft bearings. As the cylinder, which weighs 9 or 10 cwts., revolves always in one direction at a steady rate

of 140 to 170 revolutions per minute, and as the pull of the driving strap is usually towards the front, it will be perceived that a tendency, at least, will always exist towards wear in the brasses at their front side. Thus it is possible that in addition to the necessity for providing for the lessened circle, it may be also requisite to take into account the movement of the centre in a horizontal direction. The latter difficulty, however, has been to a large extent overcome by the elongation of the bearings, which are now much longer in proportion to the diameter than was the case formerly. The reverse side of the argument contends that any compression of a working part of a machine is theoretically defective and cannot be satisfactory in practice, and that it is difficult to conceive of accuracy being attained by such a plan as this. While it is probably true that the arrangement of the metal is such that it lends itself easily to compression, it can hardly be seriously contended that a forcible forming into shape is a desirable procedure for any part of a machine which has such an important function to perform. The shape of the bend is carefully designed to lend itself easily to compression, but as it is impossible in casting to guarantee the homogeneity of the iron composing it, it follows that one part of the bend may compress or spring with greater ease than another, and instead of forming a true circle may present a very irregular surface. That this form has met with approval in the past is quite true, but in mechanics this is no argument for the retention of any mode of construction the improvement of which is possible. At any rate it may fairly be contended, if not conceded, that if an accurate adjustment of the bend can be attained without the application of force a very distinct improvement is effected. There is no necessity for going so far as some have gone, and declaring that the employment of a flexible bend is altogether a mistake, because if it is constructed in such a way as readily and easily to assume the necessary shape without straining, it is a most convenient and effective means of obtaining the result. This point need not be laboured, as if necessary it can be more fully gone into hereafter. Before leaving the consideration of this special form it may however be pointed out that one firm of machinists, Messrs. John Hetherington and Sons, finish their bend after it is placed upon the machine. The

bend which is made slightly larger than necessary, is bolted to its place and is set accurately with the cylinder. As soon as it is locked up it is loaded between the setting points with a weight equal to that of the superincumbent flats and chains which traverse it. An apparatus with two circular cutters, driven by bands from the shaft, is attached to the cylinder. A slow circular traverse is given to the cylinder by suitable means and the upper edge of the bend is thus milled up so as to be, when subjected to its actual working conditions, quite concentric with the cylinder. Of course, as soon as an alteration of shape is required from the exigencies of working, it is necessary to adopt the same plan as with the ordinary flexible bend. It will be quite clear that this method overcomes a good many of the difficulties of the ordinary flexible bend, as the bend may be dropped after milling, as much as is necessary in actual work, without the development of any inaccuracy which can be measured by the ordinary means, or which is likely to effect the actual working of the machine.

Of the machines other than those constructed with the flexible bend of the kind thus described, there are several which differ only in the fact that the setting is effected in another way, the bend remaining flexible. Looking for instance at Fig. 2, which is a side elevation of the machine made by Messrs. Curtis Sons and Co., the bend has at the points C, C, C, C four brackets formed on it, which are constructed with ribs accurately turned. These form a recess in which an eccentric, working on the pin shown with a nut at the end, is fitted. A ring is fitted on the frame side B on the edge of which segments of toothed racks are formed, engaging the four sectors shown, these being cast with the eccentrics. One of the racks is fitted so as to gear with the worm D, by revolving which it is clear that the ring will be moved circumferentially, and the movement communicated to the sectors. In this way the eccentrics are rotated, and the bend being flexible, is drawn downwards or pushed upwards according to the direction in which the rotation of the eccentrics is made. As soon as the requisite distance has been traversed by the bend the nuts shown are tightened up and it is locked against the frame B. It will be seen that this bend is flexible but that the setting is made from one point.

Fig. 3 is the mode of construction employed by Messrs. Dobson and Barlow. The engine side A has attached to it three brackets C, with their upper edge inclined to the necessary angle, which varies with their position. A fourth bracket D is also fastened to A, and has its inner surface inclined in a similar way as the three brackets C. The bend B has attached to it four pins carrying small runners, one of which rests on each of the brackets C and the other slides along the inner surface of D. To the other end of B is connected in the manner shown the crank E. At D the inner edge of the bend is formed into a rack in which a pinion gears. It will be seen that by revolving the latter the bend B can be moved circumferentially in either direction, and the pins fixed in it will either ascend or descend the inclines of the brackets C and D. The motion of B towards D causes the lever E to exercise a pull on B, thus establishing a tension which keeps the pins in the bend firmly down on the inclines C. Here again the idea is to set from one point but the flexibility of the bend is made use of in a different way to the preceding example.

Fig. 4 represents the carding engine as made by Messrs. Howard and Bullough. The idea here is a very good one, and consists in the employment of inclined surfaces for the purpose of lowering the flat. The first person who employed such a device was Mr. Thomas Bispham Kay, who in 1870 patented the use of a segment of a ring with an upper inclined surface, on which the end of the flat, which was bevelled to correspond, rested. The chief defects of this arrangement were, briefly, the troublesome operation involved in forming the end of the flat, especially in giving it the necessary "heel," and secondly, the difficulty that existed when the card was working, and there was considerable vibration, in maintaining the flat in its true position over the cylinder. It will be at once understood that, unless some means were taken to prevent end play of the flat, the inclined surfaces at its ends would ride upon the inclines. This would result in the wire at one end coming into contact with the cylinder wire, and that at the other being removed from the latter. As the setting is very close a very small amount of this side play would result in serious difficulties. Now in the machine illustrated in Figs. 4 and 5 the coned surface B rests

upon and slides on the bracket or arm shown, which is cast on the side of the machine. Its upper surface is turned accurately in a lathe so that if the flats travelled on this surface they would be perfectly true with the cylinder. The segmental ring B is also formed with great accuracy. A segment of a thinner ring marked C is so turned that its inclined surface corresponds with that of B upon which it rests, while its upper surface is horizontal so as to provide the best shaped course for the flats. The action is as follows:—The screw A is formed with two threads on the micrometer principle and is passed through the frame of the machine, having an indicator finger E on its outer extremity. The dial plate D is graduated and a means is thus provided by which not only can the ring B be withdrawn very delicately by the screw, but the amount of its withdrawal can be readily seen. The ring C is made of such a section that the weight of the flats is sufficient to keep it in contact with B. It is apparent that when the latter is withdrawn or advanced the flat end will be either lifted or lowered.

The last of this series to be noticed is the form illustrated in Figs. 6 and 7, this being also the last invention chronologically. In this case the side of the engine is formed as shown in Fig. 6 of a spiral shape, that figure being diagrammatic. On this spiral is a flexible bend B which is formed with its inner surface the same spiral but with its outer surface concentric with the cylinder. It will be obvious that by moving B along the surface A, a vertical adjustment of B is possible, the latter being so constructed as to accommodate itself to its bed with ease. As the pressure on B is directly downwards and presses it on to the surface of the engine side, the course for the flats is firmly and solidly formed. This contrivance is the invention of Mr. T. Knowles, and the machine is made by Mr. J. Tatham.

All the preceding examples are modifications of the flexible bend in which the prevailing idea has been that of easy setting. To discuss the question as to which of these devices is best adapted for the purpose would lead to a larger argument than time will allow, and it will be much more preferable to leave this to other speakers. It is only necessary now to consider two other machines in which this device is left entirely at one side and others substituted. In Figs. 8 and 9 a sectional and side view

of a plan adopted by Messrs. Lord Brothers is shown. On the engine side, at its upper portion, are a number of ribs which are planed so as to be in a radial line with the centre of the cylinder. Between each pair of these ribs brackets or plates C are fitted, the upper edge of which are turned to the requisite circle to bear the flats. The brackets are divided into groups of three, each group being coupled by a pin E, fitting in such a way as to have free movement and forming a sort of toggle joint. The plate G is fitted over the whole of the brackets, being fastened to the centre one, each end of G being, as shown, attached to the centre bracket of the outer groups by a pin and also being fitted between two bowls placed on pins fastened to the bracket. Under the centre the screw F with a worm wheel B formed at its lower end is placed, resting as shown, on the arm A cast on the engine side. It will be seen that as the worm wheel is revolved by a worm, suitably placed, the whole of the brackets C being practically tied together in the manner described will be simultaneously moved vertically. In order that the alteration of the circle caused by this necessary movement shall be reduced to a minimum, the final formation of the curve at the upper edges of the plates is made when they are about ¼inch below their uppermost position. It should also be stated that the edges of the brackets are made angular so as to overlap each other, and so prevent any dipping of the flat in passing over the space between each pair which would otherwise take place.

The only machine which now remains to be considered is one made by Messrs. Ashworth Brothers, the method of construction being altogether different from any previously referred to. On the top of the engine frame D (Fig. 10) a number (about 15) of thin steel bands H are fitted, being held at one end by the stud I, and kept in tension by means of a screw E which keeps all of the bands firmly in position. These bands are not all of one thickness, but vary from about $\frac{1}{100}$th to $\frac{1}{30}$th of an inch. The end of the flat traverses on the bands, and when wear of the wire occurs one of them can be taken out and replaced by a thinner one as desired. Thus the concentricity of the flat course is accurately preserved, provided that the amount of wear to be taken up corresponds with the difference between the

thickness of the band taken out and that replacing it. It may happen that the amount of wear to be provided for is not enough to justify the removal of a band, which, on account of the necessary labour involved, takes some little time. In order to afford a ready means of making the correction and at the same time avoiding the replacement of the bands, the makers have adopted the bold but ingenious plan of forming the cylinder bearing so as to be adjustable vertically. Referring now to Fig. 10 it will be noticed that the engine frame D and the pedestal S are cast in one piece bolted on to the lower frame. The pedestal cap is fastened by means of set screws, but the bottom brass can be lifted by means of the vertical screw shown in dotted lines. This screw is fitted into the pedestal, which is tapped to correspond, and has at its lower end a ring which is divided into 100 parts on its circumference. An indicator finger is fitted so that the ring can set to any of the divisions as desired, and when so set the screw can be locked by a lock nut. By proportioning the pitch of the thread it is clear that any desired lift can be obtained. The pitch adopted being $\frac{1}{10}$th of an inch, a revolution of the screw one division on the ring would mean a vertical movement equal to $\frac{1}{1000}$th of an inch. Now it is quite true that in a sense any vertical movement of the cylinder destroys the concentricity of the flats, but this after all is a relative matter. If reference is made to a drawing showing the arc occupied by the flats in various positions, it will be seen that with a total fall of $\frac{3}{8}$ths of an inch the difference between the ends and centres of the arcs described does not amount to a great deal. Therefore if the cylinder was raised by the screw about $\frac{1}{8}$inch it would not amount to an inaccuracy of any magnitude. But as the thickest band is only $\frac{1}{30}$th of an inch thick it would be most likely that instead of lifting the cylinder anything like $\frac{1}{8}$inch a band would be taken out and the wear thus compensated for. Now the raising of the cylinder $\frac{1}{30}$th of an inch would practically mean that the setting of the flats would remain unaltered.

From these necessarily brief descriptions of the several methods of construction adopted to provide an accurate method of setting the flats, it will be seen that a considerable amount of ingenuity has been expended. Each of these separate designs

has its advocates and opponents, and it will be interesting to have the opinions of experts on the subject. This paper is not designed as a controversial one and no comparisons are made. It will, however, be as well to deal with the various machines so as to give the general ideas nnderlying the mechanism. In the ordinary flexible bend there are three setting points, and the setting has to be effected without the aid of any indicator. In the methods which are illustrated in Figs. 2, 3, 4, 5, 6 and 7, the principle of setting from one point is adopted, indicators being in all cases adaptable, if not actually in use. In the examples in Figs. 2 and 3, the flexible bend is pressed into shape by the action of mechanism, while in Figs. 4, 5, 6 and 7, the flexible ring is held down on its sustaining surface by the weight of the flats only. Thus while employing the flexible bend the same idea predominates, but there is a good deal of difference in the way in which it is practically applied. With reference to the two other machines it only needs to be said that in both cases the means employed are ingenious and worth special study. It may, however, be pointed out that the central idea in all but one of the machines which have been described is to provide a means of setting the flat course from *one* point. Now it may well be doubted whether the saving of time effected by this is really so great as might be thought. The necessity for adjustment does not arise more than once every two or three months, and that being so the time occupied in doing it does not become a matter of much concern. So far as the possibility of improved setting is concerned and the better maintenance of a more concentric flat course, all these devices are to be welcomed as tending to that end.

There are a number of other points which require a mention. In the early days of the use of this class of machine it was very usual to make the cylinder the full width of the lap, and not to clothe it all across. The result of this arrangement was that the cotton would spread out on the cylinder and form a fleece, which, when doffed, presented a ragged and uneven edge or selvedge. Messrs. Ashworth Brothers first appeared to recognise this fact, and arranged a plate which acts as a sort of flange for the cylinder, thus preventing draughts of air from being formed and the lap from spreading. Other machinists have now made

applications which have the same effect, and the general result is a great improvement. Beneath the cylinder and taker-in a series of bars with blank places between, forming an under-casing or grid, are placed through which leaf, motes and similar impurities freely fall, and knives with their edges facing the teeth of the licker-in are set in a position near it, so that as the cotton is carried forward the motes are removed or knocked off. Over the doffer, cylinder, and taker-in, polished covers are fitted in such a way that no space is left by which a current of air can pass when induced by the rotation of the cylinders.

As will have been gathered from the preceding remarks the construction of these machines involves a good deal of accurate work and, indeed demonstrates the great change which has taken place with regard to the methods pursued. By the courtesy of Messrs. Wm. Collier and Co., a number of photographs are exhibited of machine tools made by them for manipulating the various parts of these machines; a brief description of which will not be without interest. The Cylinder Turning Lathe is constructed with a hollow face-plate, by means of which one end of a mandril carrying the cylinder is sustained, and by which it and the cylinder are rotated, the other end being borne by a supporting bracket. The lathe is fitted with two rests, carried on a slide, each rest carrying a roughing and finishing tool. The rests are provided with a self-acting traverse motion. and are capable of transverse adjustment to suit various diameters of cylinder. The lathe for turning the doffers is similar in construction, but of course smaller in size. To turn the licker-in a duplex lathe is employed, fitted with two speeds to each headstock and clutch motion, permitting each head to be used separately. Each carriage is fitted with a rest carrying roughing out and finishing tools, so as to finish the roller at one operation. The rests and headstocks are adjustable.

The cylinders are, as will be known to some of the members, built up with loose ends, which are securely fitted to the shell of the cylinder. This entails the use of an ending out machine, by which the recess in the end is formed. The cylinder is chucked in two circular chucks and gripped by steel set screws, these being better than dogs, not being so liable to spring the cylinder. The chucks are revolved by means of a bed shaft,

fitted with sliding pinions gearing into external wheels attached to the chucks. There are four rests, two at the back and two at the front, thus enabling the cylinder to be bored out at one operation. A similar machine is used for the doffer. After turning, the cylinder is drilled, being placed on a mandril which is supported on two stays, and which are in the same horizontal plane as the drills. The latter are 20 in number, and are driven by a continuous worm and worm wheels geared so that each spindle revolves in the same direction. The drill headstock is adjustable along the cross slide, and is fitted with a dividing arrangement which enables the right pitch of the holes to be easily attained, it being only possible at first to drill part of the holes required. On the same bed are fixed two smaller headstocks with separate driving, which are employed to drill the holes in the internal flange of the cylinder for fixing the ends. Both these headstocks are adjustable.

The machining of the flats and their subsequent adjustment is one of the most delicate operations involved, and is worth a special description. The first operation is that of milling two surfaces at the upper side of each end of the flat, at the same time trueing up the faces of the ears to which the chain is attached. A double-ended machine is used, fitted at each end with an instantaneous grip chuck, at the bottom of which is a steel face on to which the ends of the flat are placed, the flat having been previously stretched and straightened. The flat is then cramped down, and the cutter brought into operation. The flat is placed on the faces thus formed in the next machine, which is constructed with chucks at the end of two long radius arms. A cross spindle has a worm fitted on it which gears with a segment at the end of the arms, and by revolving which the flat is brought under the cutters, and has a hollow cut into it of the desired radius. The flat is then chucked edge up and milled by a cutter on its upper side at the ends, so as to provide the necessary clearance for the chain. The next operation is to cut out by means of a similar machine to the one with the long radius arms the under surface of the flat end, which had been treated by that machine, so as to leave two surfaces on which the flat travels, the radius arms in this case being shorter, as will be seen. These surfaces have two

objects—to lessen the friction when the flat is travelling, and to allow of the flat having the necessary heel given to it. The flat is then cramped down on the surface thus formed, and the snugs are drilled by a double-ended machine fitted with an automatic motion for withdrawing the drill. By the same machine the hole is tapped, the tap reversing when it has gone the requisite depth. After drilling the flat along the edges in order to enable the clothing to be fastened, it is complete so far as its treatment by machines is concerned.

There are one or two things to notice in respect to the operations just described. The first is that all the faces are formed from that on which the wire clothing is subsequently placed, and that consequently the flat when traversing is provided with working surfaces which ensure it being parallel to the cylinder all across, provided the bends are correctly set. This is, as will be seen, an important point. Again, the whole of the surfaces to which the chains are attached are true with the flat ends, so that there is no tendency to pull the flat askew. Having thus obtained, by the means indicated, the flat as perfect as it is possible to do by machine, it is necessary to put the "heel" in, and also to correct any twist which may have arisen by the spring of the flat whilst being milled. There are two methods of doing this, one mechanical and the other electrical. As will have been noticed from the description of the method of milling the flats, two parallel surfaces are formed at the upper and lower side of each end of the flat. The lower one is used as a surface on which the flat travels, and the upper one as a surface on which the flat is held during the grinding of the wire. It will be evident that, if the flat is placed upon either of these surfaces and tested by a suitable apparatus, the other surface should be as nearly as possible parallel with the first. In order to see that this is so, the flat is placed face downwards on two steel faces perfectly parallel with each other. At each end of the table carrying these faces is an indicating apparatus consisting of a graduated scale and two pairs of compound levers, so arranged that a slight inaccuracy is multiplied to a large extent. Now it is clear that if the flat is laid on the blocks and the points of these levers are allowed to fall on the four surfaces left after the flat is milled by the long and short radius machine,

the setter can see at a glance if the surfaces are accurately formed. In practice, the two ridges or surfaces at the front of the flat, that is the edge nearest to the doffer end of the card, are reduced somewhat by hand, thus throwing up the back edge. This is what is known as giving the "heel" to the flat, and its object is to leave a slight space between the wire points of the flats and the cylinders at the back of the flat, while at the front these are as close as possible together without touching. The object of this is to prevent a rolling up of the strippings and cotton fibre, which has been found to exist where the wire at the back of the flat nearly approached that of the cylinder. The heel having been given the flat is then tested by the apparatus described, but instead of all the fingers corresponding, this only occurs with the two which are in contact with the same surfaces on each edge of the flat. One pair registers the variation caused by the heel and should correspond, while the other pair registers the position of the untouched surface and must also correspond. This device is the one most commonly used, and gives very accurate results. Messrs. Howard and Bullough adopt an electrical test which is also said to give good results. Similar devices are used in some cases to set the bends accurately with the cylinders, in other a simple scriber or pointer being used and set down so that a small slip of steel can be easily moved across the bend under the point. As the latter is carried in a bracket fixed to the cylinder the bend can easily be tested all round. Messrs. Howard and Bullough use an electrical scriber, contact with which rings a bell, and thus indicates the point requiring adjustment. The use of the graduated indicators as shown in Fig. 4 enables this to be easily made, and delicacy of adjustment attained. Another point in connection with the machine made by this firm is that the cylinder bearing is so constructed as to allow of the cylinder being adjusted in case of the forward wear previously referred to.

The wire clothing used for the purpose of covering the cylinders, doffers and flats, is well known to most members, it being a familiar object in most engineering works. Few people, however, have any idea of the great care which is expended on its manufacture, and although that is to a large extent beyond the scope of this paper, a few words on the

subject will not be without value. The manufacture of this clothing received a great impetus from the invention by Dyer of the Automatic Card-Setting Machine, and the adoption by Walton and Horsfall of a combination of India-rubber and Cloth to form the matrix for the wire. The value of such a material arises from the additional flexibility derived from its use, and the better support given to the wire as compared with leather, which had previously been almost entirely used. During the last few years a great change has taken place in the shape of the wire and the material of which it is made. Formerly, a very high-class of iron wire was used for this purpose, but the advent of steel and the large supply of cheap wire thus obtainable, has led to that material being almost exclusively used. The wire is now all hardened and tempered prior to being used in the setting machine, and the general effect is one which is highly satisfactory. With regard to the shape of the wire, the point at which all makers now aim is that of producing a tooth with a point as fine and near a needle point as can be obtained. To enable this to be done necessitates a good deal of careful treatment, and was first emphasised by Messrs. Ashworth Bros., to whom a good deal of the credit for this advance is due. The wire employed by that firm is round, but the teeth are ground on each side so as to make them of an oblong shape with a very fine point. Messrs. Whiteley, of Halifax, grind their wire so as to give a sort of oval wire, the point of which is very sharp. Messrs. Law, of Cleckheaton, make their wire double convex, and Messrs. Walton use triangular wire. The object of all the firms named is to provide a wire which, while having a point which is very sharp at first, retains its sharpness when ground after working, and which is of such a shape as to resist as far as possible the pressure put upon it in the direction in which that is applied, that is the direction of the circumferential movement of the cylinder. The wires are set angularly from the surface of the fillet, and after passing through it for a time are bent at an angle in the opposite direction (Fig. 12). The extreme point of the wire as shown is ordinarily in advance of a radial line drawn through the centre of each tooth where it passes through the foundation. The effect of this is that when the tooth is pressed back, as it

grind the flats while they are face *downwards*, and travelling on the surface with the heel in. It appears to the writer to be a great *desideratum* to grind the wire surface of flats in such a way as to preserve the heel, and it will be interesting to note the success or non-success of the plan of Messrs. Howard and Bullough. It would, however, be convenient if this could be attained while retaining the plan of grinding the flat, face up, and Messrs. Hetherington and Sons have devised a novel plan for this purpose, but nothing can be stated except that while the grinding is perfectly performed, the heel is accurately and constantly preserved.

The machine thus described is one which but for the enormous strides made in the accuracy of workmanship during the past few years could not have been successfully made. It is not a new type, having been made by Mr. Evan Leigh many years ago, but it had fallen into disuse by reason of certain developed defects which were apparently mechanical and not intrinsic. Now it has become the machine of the day, and is everywhere being adopted. The adoption of template work has facilitated this revival, without which the successful making of this machine could not have been attempted. It is preferred on account of the large amount of work which it can turn off, from 7 to 10 hundred pounds per week being obtained with a percentage of waste of about 5 per cent. It is hoped that this description will have been of some interest, it having been the desire of the author to present in a fair and impartial way some of the difficulties to be overcome, and the methods adopted to achieve that end. The writer has to express his acknowledgments to the Editor of "Industries," Messrs. Whiteley & Son, and Messrs. Dronsfield Bros., for the loan of the blocks by which the paper is illustrated.

ADDENDUM.

Subsequently to the reading of the paper, the author has had his attention called to one or two matters which deserve a special mention. With reference to the construction of Carding Engines with flexible bends, it might perhaps have been mentioned that Messrs. Platt Bros. & Co.,

Limited, and Messrs. Asa Lees & Co., Limited are both makers of this class of machine, and have made many thousands during the past few years. As all other machinists are named, it is only just that this fact should be mentioned. The general question of the flexible bend is dealt with fully in the discussion. With reference to the machine of Messrs. Dronsfield Bros., for feeding the filleting to the cylinder, it might be understood that it was attached to a special framing; this is not so, the framing used being that of the carding engine itself. The clip used by Messrs. Whiteley & Sons for fastening the filleting to the flats is applied as follows; one edge of the filleting is fastened to the flat along the whole length of the latter, after which the fillet is drawn tight over the *whole* surface, and the clip is then pushed through the fillet, and fastened. The top of the clip, after it is fastened, protects the clothing from abrasion by the revolving brush during the cleansing of the flats.

DISCUSSION.

Mr. John Taylor pointed out that the essayist had only referred to what were simply termed the revolving flat strippers, no account having been given of the roller and clearer type beyond a remark or two to show the advance attempted to be made by the introduction of the former. He (Mr. Taylor) did not take it for granted that the use of the revolving flat stripper was so universal as described, because in certain departments of trade it had not made any headway. It had many drawbacks, a prominent one being that admitted by Mr. Nasmith himself, namely, the difference in the diameter of the cylinder consequent on the grinding down and the reduction in the length of the stripping teeth. It was acknowledged that that was a defect which had yet to be overcome, and so far the only attempt to remedy it mechanically had been Ashworth's device. It was well known that in cotton carding the close setting destroyed the fibre, and more damage was done than advantages accrued from that means. He could not speak positively on the subject,

but from the description given to them he should certainly say that there was no operation which offered a true mechanical formation of the traverse of the flats to meet the requirements of the teeth of the card other than that of Messrs. Ashworth. With reference to the revolving flats, he might say that it was so far back as 1830 to 1835 when Mr. Bodmer, a gifted genius in mechanism, first took that subject in hand, and in the latter year took out a patent for the revolving flat. He believed Bodmer made a very elaborate piece of mechanism to meet the position of the varying diameters of the teeth caused by the grinding of the card, though he should hesitate to say that it was better than Ashworth's idea.

As regards grinding, he supposed it was the most important item in the preparation of the cards, since unless its construction was such as to ensure a regular surface all other advantages were of no use. Of the many devices tried, to his mind none gave such satisfactory results as the ordinary roller mounted on a strong shaft in order to keep it straight, with a small traverse, and so far he thought there was not sufficiently reliable data forthcoming to prove that it had yet been entirely superseded. In his opinion the greatest improvement that had been made in connection with the cotton carding engine was not in the card itself but in the coiler, the original patentee of which being a Mr. Cheetham.

There was no doubt that the better mechanism of machinery had enabled us to attain higher speeds, which in the natural course of things brought about a greater production at less cost, and it was well that such was the case, since the cotton trade of this country was at present on such narrow lines that every little saving was an absolute necessity.

Mr. Beastow asked if the cylinder and the revolving flats worked equal distances from each other or concentrically; also what was the distance from the licker-in to the coiler?

Mr. Nasmith replied that the cylinder and revolving flats worked concentrically, and that approximately it was 6 feet from the licker-in to the coiler.

Mr. Hans Renold said the reason that the number of revolving flat cards in use at the present time was still small was that these latest improvements were not more than three or four years old. In saying that he did not dispute that Bodmer in 1835 originated the idea, and that since then those engines had constantly been made but to a limited extent. One of its earlier faults was that the flats were made 2 inches wide, whereas now they were only $1\frac{3}{8}$ inch. Another fault was the want of that accuracy in the making of the cards which was now deemed necessary. Such accuracy had only of late years become possible since special tools for special work had come more into use.

To Messrs. Ashworth Bros. certainly belonged the credit of having first (now three or four years ago) given that special attention to preciseness and careful working out of detail which was now observable in the modern carding engine.

When alluding to this special accuracy he spoke from experience as a maker of the chains used in these engines. Steel chains were now being made with from 100 to 120 joints (flats) the total length of which was not allowed to vary a 50th part of an inch from the standard.

Mr. T. Knowles (Bolton) thought that there was a mechanical principle involved in the main question brought before them by the essayist which could not fail to interest anyone with scientific notions or mechanical ideas. That main principle appeared to him to be the manner of lowering the flats as they were ground and required to be brought into approximation of the cylinder in consequence of the wear and tear caused by the grinding. Mr. Nasmith had referred to several methods employed to overcome the difficulty, including Ashworth's device. The latter got the true circle by dropping down the flats concentrically, in a word by abstracting various packings, a means by which he frankly admitted they maintained a true circle throughout, and had also a rigid bearing for their flats, which was a decided advantage compared with the ordinary flexible bend. This method he must confess, with all due respect, seemed to be a sort of rule of thumb manner of getting over the difficulty, and one which he thought was far from

scientific. Mr. Knowles then deferentially drew their attention to a device of his own described by Mr. Nasmith on page 13, in which he said there was an absolute rigid basis for the flat, while at the same time a true circle was maintained throughout.

Mr. T. R. Marsden remarked that he was a firm believer in the flexible bend. Many people were under the impression that a flexible required a deal of bending, but as a matter of fact it only required bending to form part of a circle three-quarters of an inch less at 50 inches diameter. Assuming that the flexible bend was one-third the circumference in length, it would be found when it was set down in the centre three-eighths of an inch that the ends would only require bending-in a little over one-eighth to form the smaller diameter. The ease with which it was moved and set, with the facility for following down any wear in the cylinder shaft, coupled with care in its manufacture, gave a good and true guide for the flats when at work, and in which no error could be detected.

In his opinion, a card which was so constructed that the centre of the cylinder required moving for setting flats, or to make good any wear in the bearings, would never hold a permanent position in this country, as he contended that when once the centre of the cylinder was moved the basis for good work was removed.

There was a great deal of talk about indicators of one sort or another, for setting flats, and he had seen several used, but he had not seen the man who after setting with the indicator had courage enough to put on the strap before he tried those two useful indicators, the ear and touch.

His wish was that they in Lancashire should make a card which would bear out their character for good workmanship and skill in that particular department.

Mr. Wm. Taylor said during the last few years flat cards had been more generally used, owing in a great measure to the requirements of the trade demanding finer and better finished goods, and also to a great deal of prejudice having being overcome. Until lately, a good many spinners had the

idea that these cards were not suitable for coarse or medium counts of yarn, but now they were successfully in use for all classes of cotton.

The great improvement in making the wire clothing for cards had enabled the flat card to compete more successfully, increasing its production from 50 to 100 per cent, and at the same time greatly reducing the labour of stripping and grinding. He had studied all the latest designs of flat cards, and it was his opinion that the ordinary flexible bend was more simple and equally as effective as any system of bend made at the present time; it had advantages over fixed bends and those that were arranged to set from one place, as every part of the circle could be adjusted separately, and any alteration of the centre of the cylinder could be followed by the bend. He might say there were cards made with the ordinary flexible bend, with three setting places and two extra supports between the adjusting screws that could be set to the utmost nicety, which were producing the best quality and quantity. All the cards described by Mr. Nasmith had practically flexible bends with one exception, that shown in Fig. 10. He would just notice Fig. 3, which shewed a flexible bend resting upon five inclines, and was adjusted at one place by sliding the bend forward. This bend depended entirely upon the weight of the flats holding the bend down on to the inclines, which should be of different angles to compensate for the movement of the studs in changing diameters. It was a very difficult matter indeed to set flats from one place, as the adjustment must cease the moment the flats were down in any part of the circle, whether they were right all round or not.

Figs. 4 and 5 were another type of flexible bend in the form of a cone. The indicator shown for adjustment was all very well as a guide, but could not be entirely depended upon; after the cards had been at work some little time, the old system of setting would have to be resorted to. There was also an adjustment for the cylinder in this card to compensate for its wearing forward, for if the bend was set to follow the cylinder the path of the flats would become twisted. These movable centres were not desirable, for when once changed they were not easily set right.

Fig. 10 shewed a fixed circle or path upon which the flats travelled, and were adjusted by taking out one of the steel ribbons, supposed to vary $\frac{1}{1000}$th part of an inch in thickness. It was all very well to say that with ribbons of such fineness this card could be set perfectly, but it would be found after grinding that in changing the steel bands it would either be too much or too little, and then the only remedy was to move the centre of the cylinder, and in doing which the concentricity was lost and the flats were inaccurate. This difficulty would also be found, that after the cylinder had been working some time and worn a little forward, the flats would be nearer at the front than at the back, and this defect could not be remedied so easily as in the case of the ordinary flexible bend, which could be adjusted to follow the cylinder and set perfectly accurate.

On the motion of Mr. Thomas Ashbury, seconded by Mr. B. Marsden, a hearty vote of thanks was awarded to Mr. Nasmith for his valuable contribution to the records of the Association.

Mr. Nasmith suitably acknowledged the vote of thanks. In reference to the discussion he said there was really very little to reply to, the only question in dispute being that of the relative merit of the flexible bend and those other devices which had been described. Now while it was quite true that the flexible bend had the defects which had been pointed out, it was another thing to say that these were entirely overcome, or that better carding was obtained by the use of the newer plans. The moving of the cylinder centre owing to wear was a thing which could be easily provided for with the flexible bend, but was not so readily met in the other cases. He agreed with Mr. Wm. Taylor and Mr. Marsden that it was an undesirable thing to move the centre of the cylinder, but this, like many other matters in connection with the subject, was relative rather than absolute. There was little doubt that this was recognised as an evil, and he believed Messrs. Ashworth Bros. were trying the plan of driving from below so as to get a straight pull om the strap. This would not entirely overcome the forward caused by the revolution of the cylinder, but it would

to a certain extent do so. At the same time, the flexible bend depended upon the skill of the person setting it, and this was attended with all the difficulties usually arising from that source. It was certainly true that the use of an indicator was difficult, owing to the fact that it was not easy to ascertain how much had been ground off the wires of the cylinder and flats, upon which depended of course the movement of the flat course. The relative merits of flexible bends of the ordinary type, and the various improvements named, was a subject upon which no one could give an absolutely infallible opinion. There was a good deal to be said on both sides, and personally, he did not pretend to have a definite opinion antagonistic to either system. One thing appeared to be very likely, and that was that the extreme speeds at which engines were driven, the method of setting the wires equi-distant all over the flat course, and the use of wire clothing of the same counts throughout the flats were not likely to give such good carding as the carding engines with stationary flats. The latter could be set so as to be further from the cylinder at the beginning and nearer to it at the end of the bend. In addition to this, the wire clothing used could be arranged so that the cotton was, in a sense, carded by stages, beginning with a coarser wire and ending with a finer one. In this way the carding was better, and less damage was done to the cotton. It was a doubtful thing whether the increase in speed and production obtained from this modern card was as productive of a good yarn as the self-stripper. The cotton fibre, as was known, was covered with a sort of waxy sheath, the removal of which was very prejudicial; and it did appear to him that there was a danger, under the modern high pressure, of damage being done to the cotton. This was a matter however, somewhat beyond the scope of the paper; but it would certainly appear that slower speeds and more machines would be likely to improve the quality of the yarn produced. With reference to the evolution of the revolving flat card, the real originator was James Smith, of Deanston, near Glasgow; but it was not until Mr. Evan Leigh's time that any, even partially successful move was made towards its general use.

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ELECTRIC LIGHTING FROM CENTRAL STATIONS.

A PAPER

READ BY

MR. J. R. WILLIAMSON,

M.S.T.E., &c.,

(Member of the Association,)

ON 26th NOVEMBER, 1887,

AT THE GRAND HOTEL, MANCHESTER,

Alderman W. H. BAILEY, J.P., President,

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ELECTRIC LIGHTING FROM CENTRAL STATIONS.

In this country up to the present time, with very few exceptions, Electric Lighting has taken the form of isolated or separate installations. There are of course, and will continue to be, many cases where the only means of having this illuminant will be in this way; and for a large works, where it is necessary to carry on processes night and day, the saving over any other method of lighting is a very substantial one. Even in cotton mills, where not more than 300 to 400 hours of artificial lighting is required per annum, it has been found to be economical. Hence, a short description of such an installation will probably not be out of place here.

We have, first of all, the motive power, which may be a steam, gas, petroleum, or hot-air engine, or where there is water-power, a turbine. We need not dwell on this point beyond saying that steadiness in the driving is of vital importance, and therefore the mill or works engine should only be used in such cases where there is not a variation of more than 2 % either way.

Next we have the dynamo. This is a machine which consists of four principal parts :—

(1) The field magnets, which are substantial masses of soft iron, wound with coils of insulated copper wire, a current passing through which renders the iron powerfully magnetic : this is simply a horse-shoe magnet on a large scale.

(2) Between its poles revolves the armature, which again consists of soft iron, with insulated copper wire coiled upon it. Nearly all the dynamos at present in use may be divided into two classes, which depend upon the manner in which the armature is wound. No. 1 diagram shows roughly a dynamo with the armature in section, in which the winding is on the Gramme principle. In this, the iron of the armature takes the shape of a ring or hoop, with the wire wound on in sections as shown. The other method, known as Siemens' winding, is shown

in diagram No. 2, where the armature is to all intents and purposes a solid cylinder of iron—it is in reality built up of plates insulated from each other—but it is not my object to pursue details of this description: the wire is wound on the outside of the drum in the manner shown, passing across the ends. In both the Gramme and the Siemens' the sections of wire are connected to the third part of the dynamo, which is called the commutator.

(3) This is built up of bars of copper, insulated from each other, and its object is to deliver the electric current generated in the armature, always in the same direction.

(4) The fourth part of the machine is an arrangement for collecting the current from the commutator, and for this purpose brushes built up of copper wires, held in suitable holders, are generally used.

The chief points to be observed in the working of dynamos are:—

(1) They should be kept clean and free from dust; any grease which may happen to get on to the commutator, should be immediately removed; a little mineral oil may at times be used for cleaning the commutator, but on no account should a vegetable oil be used.

(2) The machine should be kept in as cool and as well a ventilated place as possible; heating reduces the efficiency of a dynamo, and gives rise to sparking, which again gives heat, and thus the evil is an accumulative one, highly detrimental to the working and durability of the machine; under this head may also be mentioned the necessity of seeing to the lubrication of the bearings.

After the motive power and the dynamo, we have the main conductors and the arrangements for distributing the current, and using it in lamps throughout the building. The sectional area of all wires should be sufficient to carry double the amount of current ordinarily required, without perceptible heating; the copper should be very carefully insulated with prepared cotton, and india-rubber, with a strong outer braided covering, and further where likely to be interfered with, should be encased with woodwork.

There are a number of very important details, such as the proper arrangement of switches, and safety fuses, which it is not necessary for me to refer to at greater length. Mr. Musgrave Heaphy, of the Phœnix Fire Office, has paid considerable attention to this subject, and I have here one or two copies of his rules, which if rigidly adhered to, will prevent any possibility of fire or other danger in connection with an electric light installation. I do not wish to disguise the fact that it is possible to cause fire by electricity, but if work is properly carried out and with reasonable precautions, the chances of a fire are much more remote than with any other system of artificial lighting. This is borne out by the attitude of the insurance companies.

It might be naturally expected that any risk there may be in adopting the Electric Light would lie in the lamps themselves, but it is a simple matter to show that an incandescent lamp may be enveloped in fine muslin, and broken when alight, without even singeing the muslin. These lamps, as you are aware, simply consist of a small glass globe, containing a delicate carbon filament, which is made from cotton thread, and the globe exhausted of air as far as is practicable. Hence on the lamp being broken, the air rushes in and the filament is consumed instantaneously.

Water is the principal agent of danger in electric light installations, for if there is any defective insulation and the wires become wet, a connection is thus established with the ground; and if this takes place on both of the leading wires, a "short circuit" and leakage from one to the other is produced, which might cause the heating of some poor conducting material which happened to intervene, and unless there are adequate safety appliances danger might result.

To light a series of buildings on the system just described, would involve conductors of such weight and expense as to render the cost prohibitive in competition with gas, except for very limited areas.

Under given conditions, it is not a difficult question to calculate what sized mains should be used to give the most economical results. On the one hand we have interest and depreciation on the outlay, and on the other the cost of the energy lost in the conductors, and the calculation is simply to

strike a balance between these, keeping as a minimum such a sectional area as will safely carry the current required.

So far we have only considered what is known as the ordinary parallel system of working, and which is illustrated in diagram No. 3. Here we have two main conductors, and each lamp forms as it were, a bridge from one to the other.

Assuming the electrical pressure, or difference of potential, to be kept constant, then the flow of current is in proportion to the number of lamps in use, and each lamp is entirely independent of its neighbour. Now it will be clearly seen, that if we were to arrange two of these lamps in series, and then these pairs in parallel, the amount of current required would be one half of what it was before; of course the electrical pressure would be double, and therefore there would be no real saving of energy, but from the fact that we have reduced the current by one half, the sectional area of the conductors may also be reduced by one half to give the same loss as before, but as this loss would be on a higher electrical pressure, the percentage would be less in proportion, and therefore we may still further reduce the size of the conductors. In other words, by arranging the lamps two in series as just described, the conductors would only require to be one-fourth of the weight that would be needed in the previous case for the same loss in transmission. The drawback of course would be that to switch out any one lamp would mean that the pair would be turned out.

If now we connect the wires between the pairs together by a dummy wire, then turning one lamp out would not extinguish both, but if a number were turned out on the one side, the whole of the current passing through those on the other side, would have to pass through the remaining lamps on the first, which latter would be thereby rendered very brilliant, while the former would be much below their nominal candle power. This arrangement therefore would not do in actual work.

To get over this difficulty we have the "three wire system" of Hopkinson and Edison, the arrangement of which is as shown in diagram No. 4. Two dynamos are connected together, a main wire running from each of their two extreme terminals, and the third wire from the branch connecting the

two machines, the lamps being arranged as shown. If now a lamp be extinguished, or a series of lamps on either side, the remaining lamps and those on the other side are not affected. Still this, although an improvement on the simple parallel plan, is not sufficient, and could only be adopted with economy for installations where the furthest lamps are within a distance of 500 yards, and therefore for areas which would have say 10,000 lamps within such a radius; then, in such a densely populated part, the cost of a central station would be almost prohibitive.

We may extend this system, until we have an arrangement such as shown in diagram No. 5, in which there are 5 dynamos—D1, D2, &c., connected together as shown. This arrangement has many objections and difficulties.

It is evident and has been long known, that the only way in which distribution over large areas could be effected, would be to work with a high E.M.F., and thereby for a given amount of energy have a small current; but it has not been found practicable to construct incandescent lamps of a greater resistance than 200 Ohms. To increase their resistance, means the use of a longer and thinner filament, which is much more liable to get broken, and will not endure the passage of the electrical current sufficiently long to render them economical; and therefore we are practically limited at the present time to about 100 Volts.

Efforts have been made to work incandescent lamps in series, using low resistance lamps. The Bernstein Company have made some installations on this system, which I fear will not be widely adopted.

About four years ago a system of distribution for public lighting was attempted at Colchester, which should have been more successful than it was. It was carried out for the South Eastern Brush Co., by their Engineers, Messrs. Beeman, Taylor & King, and frequently referred to at the time as the "B.T.K." system. They made use of Brush dynamos, which are capable of giving a constant current, and a very high E.M.F. This current was sent through distributing mains, laid under the streets, and a good deal of their trouble was through the inefficient manner in which these mains were insulated. At

various intervals sets of accumulators were introduced in these circuits. These accumulators were charged from the central station, and the energy thereby stored, distributed to the lamps in the manner shown on diagram No, 6.

They had several ingenious arrangements, some of which acted, and some of which did not; among the latter may be mentioned their "Master Cell," which was intended to control the set of which it was one, by breaking the circuit when the charging of the set was completed, and re-establishing it as soon as the cells had run down to a point at which it was desirable they should be again charged.

It is a very difficult matter to completely insulate a set of accumulators from the ground, and therefore if a high tension current is being used for charging, there is a great tendency to leakage, and further, this tendency introduces an element of danger, from the fact that all the wires in any private house being in connection with the accumulators, are at the same time in connection with the high tension mains. Hence this system, although a very decided advance at the time, did not live very long.

There is another plan however, which it seems remarkable should have been so slow in developing, especially as it embodies a simplicity which no other previously proposed possesses.

In 1842 Ruhmkorff invented the induction coil, which has since borne his name. Diagram No. 7 is an illustration of this. It consists of a central core, which is simply a bundle of iron wires, on this is wound a short length of thick insulated copper wire, forming the primary coil. And again over this is wound a considerable length of very fine insulated copper wire, forming the secondary coil. On a low tension quantity current being sent through the primary coil, a very small high-tension current is induced in the secondary, and the instant that the current in the primary ceases or is cut off, an equal and opposite high-tension current is again induced in the secondary. This induced current is instantaneous. The principle of this was known to Faraday, and described by him in 1835. In order to keep it up it is necessary to use a contact breaker in the primary circuit, to quickly make and break the flow of the current, or a commutator to produce rapid alternations. If now we connect

the secondary coil of this apparatus with the secondary coil in a similar arrangement, the high tension alternating current which we have produced, will in its turn induce a low tension current in the thick wire of the second induction coil. Hence if we produce a high tension current, either directly from a dynamo or by the agency of an induction coil, it can be transmitted to a distance, and there converted into a low tension current for use in the lamps at our command; and transmitting it in this manner will require a very small conductor, compared with what would be needed without this induction arrangement.

In 1856 Cromwell Fleetwood Varley patented two forms of induction coils, which are substantially the same as the latest and best converters or transformers, as such coils are now termed. Diagram No. 8 shows his arrangement. In this coil we have a bundle of iron wires as the core; these wires project beyond the coil, and are doubled over and united round about it, so as to enclose the coil in a sheathing of iron. By this means the magnetic circuit is completed through iron, and not through the air, as in Ruhmkorff's. This is a very important difference.

In 1877 a patent was granted to Jablochkoff, which was followed in 1878 by the patents of Edwards and Normanby, J. B. Fuller, Bright, and De Meritens, and further in 1883 by Goulard and Gibbs' patents. These are all on the same lines, but very little was done until 1883, when Gaulard and Gibbs brought theirs prominently before the public, and in fact lighted up several stations on the underground railway by means of their induction coils, which they called secondary generators. These were connected in series, as shown in diagram No. 9, and so far as transmitting energy was concerned, were successful, but with this arrangement it was not possible to distribute electricity. By this I mean that a system of lighting could be carried out, but the lamps would not be independent of one another. They worked with a constant current, and expected that as the number of lamps in use was varied, the E.M.F. would vary in proportion: but in this they were mistaken. Their system embraced,—

(1) A dynamo producing an alternating positive and negative current of high potential.

(2) A secondary generator or converter, which was in fact a Ruhmkorff coil reversed; and —

(3) The secondary circuits, in which the lamps were placed.

In October, 1882, Edison took out a patent for "rotating transformers." These were in fact a combination of a dynamo and a motor. His idea was to generate a high-tension current at the central station, and transmit this through small conductors to distributing stations, where the current was to be made to actuate a motor, which had in combination with it a dynamo, the latter producing a low-tension current, which was supplied to the lamps. These "rotating transformers" were placed in series in the primary circuit, the lamps being of course in parallel, in the secondary. Finding that this arrangement did not work in the manner he expected, he took out a patent a year later for rotating transformers arranged in parallel with the source of electricity, and the lamps in parallel as before. This is a system of distribution on a sound basis, so far as its capabilities of doing the work proposed is concerned; but the arrangement is a costly one, and the fact that the transformers are machines in motion, and therefore require attention, is a serious drawback. The plan however admits of accumulators being worked in conjunction with the transformers, which is an important point in its favour.

Returning to our non-rotating transformers, it was not until 1885 that the advantage of connecting these in parallel was discovered; diagram No. 10. shows the arrangement as patented by Zipernowski and Deri. They proposed to use a high tension alternating current dynamo, feeding into a pair of main conductors. The primary coil of each converter being connected across these mains in exactly the same way as the incandescent lamps are connected across the mains of the secondary circuits. Of course in this case the primary coil has a long thin wire, and the secondary coil a short and thick one. The relative length of these two wires, independent of their thickness, is determined by the conversion which it is desired to make. For example, if the difference in potential in the mains is 1,000 volts, and the lamps in the secondary circuit are of 50 volts, then the ratio is 20 to 1; that

s, the primary wire must have 20 times the length of the secondary wire, and as the latter will have induced in it almost 20 times the quantity of current, it must have a sectional area of 20 times that of the primary. This decides the relative lengths only, and the question to decide the actual length of either still remains.

This is determined by the magnetic induction of the transformer, of whatever type may be under consideration, according to the E.M.F. and number of alternations per second of the primary current to be used, and it should be such that when the secondary circuit is open, that is when there are no lamps in use, the amount of current flowing through the primary is practically nil. At first sight it may appear that to obtain this it would require a very great length of primary wire, but this is not so, on account of the magnetic induction which, owing to the current being an alternating one, continually produces an opposing E.M.F. This is extremely important, as the converters whether in use or not are always in the circuit. It is perfectly possible to construct apparatus on these lines, so that there shall not be a loss of more than 2 °/₀ or 3 °/₀ either when lamps are in use or not.

Further, so long as the difference of potential in the mains is kept constant, which can be easily done, the amount of current passing is strictly in proportion to the number of lamps in use, and the potential in the secondary circuit being also constant, every lamp is independent of the remainder, and the action of one converter is absolutely independent of the others. Hence you will see that this as a system of distribution leaves little to be desired.

Apart from the lamps being independent of one another, the current in the mains and consequently the coal consumed at the central station, is proportionate to the number of lamps in actual use, and hence the system is an economical one to work.

The construction of Zipernowski's transformer or converter is the essence of simplicity. It consists of forming two insulated conductors—a primary and secondary respectively—into a core of ring form, and then overwinding them with iron wire. The only difference between this and what we have already mentioned is that the wire is inside and the iron outside instead of the

reverse; this iron also forms a complete magnetic circuit, which there is not in the secondary generator of Gaulard and Gibbs. The only drawback is, that in case of a slight fault inside, it is necessary to undo the whole of the iron sheathing, in order to get at it; on the other hand, as the wires are so well protected there is less liability to damage.

In the same year (1885), Ferranti patented a transformer, in which the core consists of hoop iron on which the two coils are wound, and then the iron is bent over and the ends joined, thus enclosing the coils; the whole arrangement is then encased in a cast iron box. This you will see is a very similar arrangement to Varley's patent, taken out in 1856.

The dynamos used with these converters as already mentioned, are high tension alternating current machines. Diagram No. 11 shows a design of such a machine as constructed by Messrs. Elwell-Parker, of Wolverhampton for this purpose. The armature consists of a soft iron wheel, carried on a steel shaft, by suitable supports, and having wound upon it a considerable number of coils of wire. These coils are passed rapidly before the poles of fixed electro-magnets, which alternate in polarity. The current is collected from two insulated rings, by rubbing contact pieces. A small continuous current dynamo is of course required to excite the field magnets.

Instead of using such a dynamo, Rankin Kennedy makes use of a low potential alternating current dynamo, in conjunction with main transformers, to produce the high tension current: this is then made use of in the manner already described. Diagram No. 12, which is taken from an illustration in his book, shows his arrangement.

The Westinghouse Company, who are the owners of Gaulard and Gibbs' American patents, have within the last year been energetically at work. Although they are working under the patents just referred to, the converters they used are very similar to Ferranti's; in fact the best construction is so simple that very little variety is possible. I have on the table a converter, built in this country by Messrs. Gaulard and Gibbs: it is intended to supply about 20·16 candle

power incandescent lamps, with 2,000 volts on the primary and 100 volts on the secondary circuit.

Diagram No. 13 illustrates the arrangement adopted by the Westinghouse Company. They use an E.M.F. of 1,000 volts in the main circuits and 50 volts in the lamp circuits. They carry their wires on poles overhead, to which poles the converters are also attached, and the lower wires on the diagram represent the secondary circuit, from which branches are taken into the buildings to be lighted. Their machines are constructed in three sizes, and the exciters only absorb 2 °/₀ of the total energy. The converters are made in several sizes, and weigh approximately 3lbs. per lamp; the efficiency is given at 95 °/₀. There are already 27 electric light stations at work in the States on this system.

Diagram No. 14 gives a comparison of the cross section of copper conductors on some of the systems we have considered This speaks for itself.

The Grosvenor Gallery installation, commenced by Sir Coutts Lindsay & Co., under the management of Mr. Ferranti, was the first in this country—(I mean, of course, on the parallel system of converters.) Siemens' alternating current dynamos and Ferranti's converters, connected by circuits run overhead, are used, and a very considerable number of lamps is nightly supplied from this plant.

There is another at Eastbourne, which I think is a better example of public lighting, although as yet nothing like so extensive. In this installation an Elwell-Parker alternating current dynamo and Lowrie and Hall converters are used. The mains are run underground, and branches tapped on where required. Diagram No. 15 gives some interesting curves, showing the output of their dynamo, at different periods of the night's run, for four consecutive nights. As they work at 2,000 volts, each ampère generated by the dynamo would be capable of supplying 30 lamps in the secondary circuits. They have an ingenious arrangement for maintaining the constant E.M.F. of the dynamo.

So far I have not referred to "Arc" lamps, because in the question of public supply of electricity, they will in all probability play a minor part. High candle-power incandescent lamps

would, it seems to me, be more suitable in the majority of cases; at the same time it is satisfactory to find that it is possible to work "Arc" lamps from converters, and thus we would have the same dynamos supplying both "Arc" and incandescent lamps, without any risk of the one interfering with the other.

The question of meters is a very important one in connection with the public supply of electricity. Professor Forbes brought one before the Meeting of the British Association in Manchester, in September last, which promises to be of good service. It consists of a short length of thick platinum wire arranged in spiral form, through which the current is caused to pass. This wire heats in proportion to the amount of current passing, and the heat causes convection currents in the air surrounding the spiral, which again rotate a small fan, and the number of turns is registered by clockwork. There are some other meters, but time will not permit of a description.

When electric lighting first came before the public, there was a great rush, and a large number of companies were floated. The public expected too much, and their speculation only brought disappointment. This was a serious blow to the industry, which is only now regaining the confidence of which it was robbed by speculators. During the last five or six years, electricians and engineers have been at work, and I have endeavoured to give you in some measure, an account of the results of their labours. Great scientific difficulties have been swept aside, but there still remains a difficulty of another kind, which has been a serious impediment to the progress of central station lighting in this country. I refer to the Electric Lighting Act of 1882, which contains restrictions under which no private company could work.

The Eastbourne Company obtained their right to run underground conductors from the Corporation, prior to the passing of this Act; hence they are in a position which I believe is unique. The Act does not refer to overhead conductors, and therefore, where the necessary permission can be obtained, work might be carried out on these lines. Still there are some serious drawbacks, and altogether such a plan is not a satisfactory one. There have been already three or four bills

before Parliament to amend the 1882 Act, but nothing has as yet been done; still it is quite certain that public interest will very soon demand the consideration of this point. All that electrical companies desire, is to be placed on an equal footing with the gas companies, with whom they do not fight shy of competition, but are anxious for it.

DISCUSSION.

The President, after referring in complimentary terms to the paper, said that the essayist had very properly alluded to the Electric Lighting Act of 1882. It certainly was very extraordinary that the Corporations in the North of England had united to prevent electric lighting being introduced into our towns. He remembered uttering a protest against the Salford Corporation being represented before a Committee in the House of Commons, in order to object to the Eccles and Patricroft Local Boards obtaining powers for electric lighting, the only *locus standi* the Corporation having for objecting to the granting of those powers being that the Boards were customers of their Gasworks. The only answer he received to his protest was that there was an amount of money invested in gas plant, and that it must be protected. Well, if that were considered a reasonable reply, anything which was promoted for the benefit of mankind, and which interfered with invested capital must be opposed on similar grounds. He thought it was a very unsatisfactory condition of affairs that a public body, without any conscience at all, should dare to object to any place supplying itself with the electric light; and it certainly behoved the ratepayers of Manchester and Salford to see if such a state of things could not be remedied.

He was not in a position to say much about electricity, but he was sure the light which the essayist had thrown upon secondary generators was useful information to all. They were practically still among the pioneers of electricity, and there was yet an amount of work to be done: the fact that the large generators in use some time ago had been reduced to the size

shewn was evidence that active-minded men were at work endeavouring to produce the light at a minimum expense of engine power, and that was really the point where the expense occurred.

Aldermam Buckley (Oldham) said he remembered the year of 1882, referred to by the lecturer, when there was such a controversy between the electricians and the various municipal authorities. He recalled to mind very vividly being a member of a deputation representing the various Corporations going up to London, and discussing the subject with Mr. Chamberlain. At that time he certainly thought that Mr. Chamberlain was championing and taking the cause in his own hands, and that the corporations were being a little roughly used. Such was the difference of opinion on the matter. He remembered Mr. Chamberlain distinctly remarking to them "You must either do it yourself or let others do it for you, and that is the spirit of my Bill," and he was of opinion that such was the spirit of the Bill at the time. What they primarily objected to was the right of any company to go into a town and select any portion of it in which to introduce their light, without any regard to the authorities who were responsible, and who had control over that town or district. He did not think that the various corporations would raise any obstacles to the operations of any company if they were brought about in such a way as would conduce to the well-being of the borough. He certainly confessed that, since that time, in watching the various phases of the electric light, he thought its progress and development had been very slow indeed.

Reference had been made to the lighting of mills by the electric light, and he could only say, as regarded its application in that direction, that up to the present time he knew of only one success.

In Oldham they had authority to light all their public buildings by electric light, and although Mr. Platt and himself had been deputed to select the best light, up to the present time they were unable to agree on any system they would like to recommend to the Oldham Town Council for adoption. He

should be much pleased if the subject could be pursued still further, and at the same time advocated in much simpler language.

He would like to know if any progress had been made during the last ten years in the generation of electricity, and if it were still in the minds of electricians that there was no other source of getting it other than by its generation in the machine. He might add that from his own observations during the last four years, in connection with motive power for electric lighting, he had come to the conclusion that one of the greatest impediments to its advancement had been the adoption of small and inferior classes of engines.

Mr. Rawlinson suggested that electric light wires and the pipes under our streets should all be carried in an underground passage, so that they could be got at without interfering with the traffic.

Mr. James Walthew observed that the essayist, in pointing out the sections of copper wire, said there was a loss of 10 per cent. on the large section and 5 per cent. on the small section: he would like to know if that was correct, as it seemed to him to be the reverse.

Mr. T. Daniels asked for information with reference to the relative cost of the Westinghouse System and Gas, and further if the time would soon arrive when electric lighting would be so perfect as not to necessitate the gas running by its side as a matter of precaution. He thought the public naturally wanted to be sure of its reliability before generally adopting it.

Mr. J. Walthew said that in a small installation which he had had the opportunity of observing, he noticed that in its first year of adoption the light was very brilliant, whereas, in the second year, there was considerably less brilliancy, in fact fully 12 °/₀ difference, although the same dynamo, engine and all the circumstances in both years were identical. Could the essayist account for this diminution of brilliancy?

Mr. Boswell referred to the adoption of electric lighting at Messrs. Wright Turner's mills in Pendleton, as the first installation of the kind in the district, and asked if the reader of the paper could give them any details of the cost ?

Mr. J. Hartley wished to know what, up to the present time, had been found to give out the best motive power for driving the dynamos. He knew that in most instances where the electric light was being adopted and where it was necessary to put down an engine and boiler, the persons adopting it had been informed that a gas engine would answer the purpose. Now, he believed, that when some of the lights were put out the engine power diminished in the same ratio, and in such a case automatic expansion gear would be necessary, in order to work economically. Against this it was a fact that gas engines when worked with a reduced load, did not work economically, nor did they give regular turning. In his opinion, to get this regular turning and economy from a steam engine in driving the electric light, it was absolutely necessary that such engine should be of the highest class, running at a high speed, and fitted with automatic expansion gear. He would like to ask the lecturer if he could give them any information as to whether gas engines gave efficient results when working at reduced power, say with half or quarter of full load. Further, with regard to mill engines driving dyna nos, Mr. Williamson had stated that they should not vary more than 2 °/₀, but he (Mr. Hartley) thought that in the present state of efficiency of that engine, if it varied even that much, good work could not be got from the mule, and in fact would be considered far from what it ought to be. As regarded electric lighting for mills, he thought the results would be found more satisfactory when the dynamos were driven by the ordinary mill engine than by adopting an auxiliary one. It would be more economical in every way, since necessarily those engines were of a higher class than the auxiliary would be; and again, in many instances, they were under loaded. In conclusion, he would like to ask if the lecturer could afford any information as to the electric light being introduced into coal mines?

Mr. T. Settle asked how it was that electric lighting was not more used in railway carriages?

Mr. Thomas Ashbury, in proposing a vote of thanks to the lecturer, said that Mr. Williamson had for some time held the post of Manager and Electrical Engineer to the Manchester Edison Swan Company Limited, having previously been the Chief Electrician to the Metropolitan Brush Electric Light Company Limited, of London, and though he had been a member of that Association for the last three years, that was the first occasion on which they had had the opportunity of welcoming him as the reader of a paper before them. In treating the subject he had begun with the fundamental principles and gone on to the most recent experience in electric lighting. The question of electricity *versus* gas was very interesting. The former could not be applied so cheaply as the latter at the present time, because it could not be used so economically. If, however, it had to be used during the 24 hours continuously, instead of in the intermittent manner in which it necessarily was, it would amply repay the initial expenses necessary to provide the motive power.

Mr. James Walthew seconded the resolution, which was carried by acclamation.

Mr. Williamson, in acknowledging the vote and replying to the questions raised, said, in reference to Mr. Buckley's remarks, that electricians did not look upon Mr. Chamberlain in the light of a friend when he completed his Bill. He (Mr. Williamson) contended that that Bill had rendered electric lighting absolutely impossible for public purposes. There were many restrictions which time would not permit of his referring to, but he might mention one clause which was in effect that after a period of 20 years the electric light contractors were to be forced to sell their undertaking, whether willing or not, if the corporation desired it. They should receive no compensation for good-will, and the price to be received should be that which might be valued by the Government or the corporations' own assessors. Now, he (Mr. Williamson) was sure they would

admit that such an arrangement was about as one sided as it could possibly be. Seeing that it would probably take three or five years to establish a lighting station, there would not be much time left to make sufficient profit to pay back the cost of the installation, and to pay a reasonable return for the use of the capital. With regard to the electric light being adopted in mills, he might say that he could take Alderman Buckley to a score or more mills in the immediate vicinity where it was working successfully; and, as regards the question of its competition with gas, he might mention an instance of a large mill, belonging to Messrs. Rhodes, at Hadfield, which had been lighted-up by electricity a year ago. The owners had since so much confidence in electric lighting that they had even ordered the gas meters to be taken out of the mill, so that now they were practically without gas. Since then his Company had received an order from the same firm to light up another mill with 900 lights. As to the progress which had been made in dynamos, and which had been referred to, he might state that, whereas five years ago they used to be satisfied with 60 or 70 % of efficiency, they were now in a position to guarantee 90 to 95 %, that was of the power actually given to the dynamo by the belt. They could guarantee this per centage, its equivalent being returned in the circuits in the form of electric energy. He quite agreed with Mr. Rawlinson as to the advisability of the wires being carried under ground, and not overhead as was at present largely the case. Replying to Mr. Walthew's question, with reference to the sections of copper wire, Mr. Williamson explained that the largest circle on diagram No. 14 represented the section of solid copper conductor, of the size required for 20,000 incandescent lamps, on the "simple parallel system," with a 10 % loss. The next circle represented the conductor required on the "three wire system," shewing an improvement. The smallest circle gave the size necessary on the Westinghouse system, for the same work, with the same loss, proving the enormous advantage gained. The third circle represented the main conductor on the same system, but with a 2½ % instead a 10 % loss.

As regards the loss of brilliancy in lamps, that was probably due to their having been over-run. The effect of this would be

that some of the carbon of the filament would either be volatilized and deposited on the glass, or the minute quantity of oxygen remaining in the lamp would oxidize a portion of it, and the carbonic acid produced might at the high temperature be decomposed, and the carbon deposited on the glass, setting free the oxygen to continue its disintegrating work. In this way the thickness of the filament would be reduced and the surface of illumination thereby diminished. Further, the resistance of the filament would consequently be increased, and therefore the intensity of the incandescence would be less. The carbon on the glass would further reduce the light. Hence the evil would have a three-fold effect in diminishing the light of the lamp.

In reply to Mr. Daniel's question as to the relative cost of gas *versus* electricity, he said that in America the Electric Light Companies had a great advantage, as gas there was three to four times the price it was in this country; but he believed it to be perfectly possible to put up an installation on the Westinghouse system which should be able to compete with gas at 3/- per thousand cubic feet. However, even apart from the mere question of cost, the public would prefer to have the electric light because it was healthier, and in private dwelling-houses, pictures, decorations, ornaments, &c., were not damaged by electricity as they were with gas.

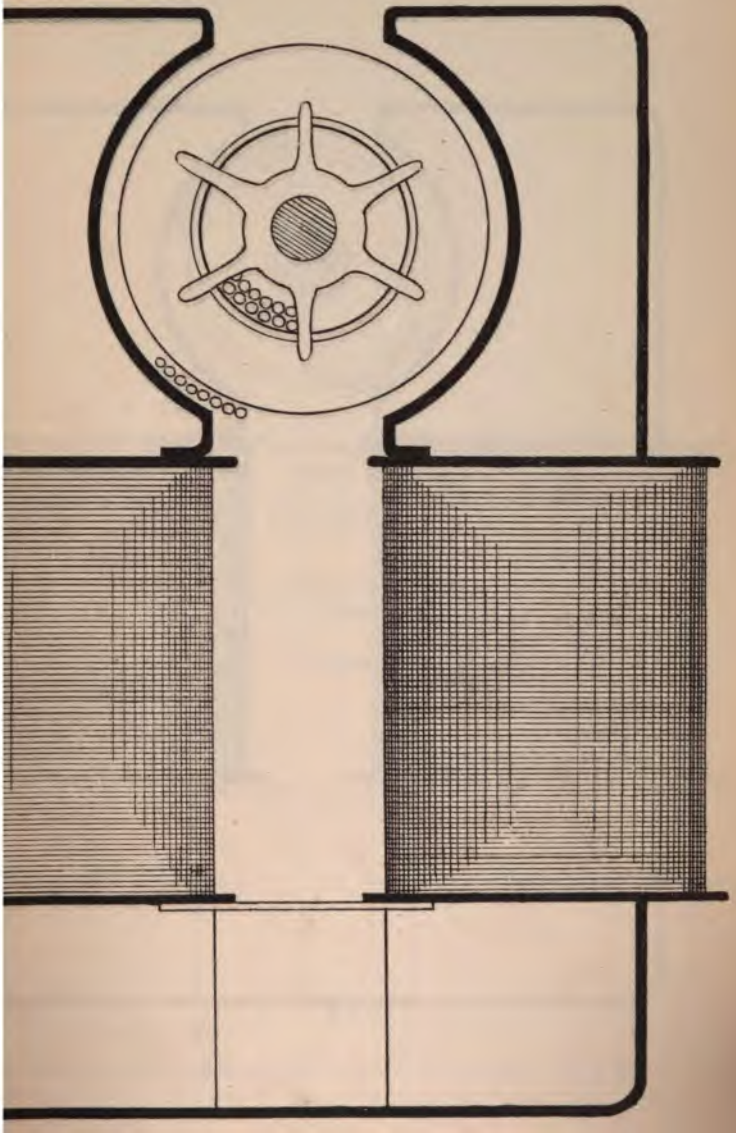
In reference to Mr. Boswell's question as to the cost of the electric light installation at Messrs. Wright Turner's mill, he might state that he had the mill manager's figures, which showed that for the 930 electric lamps put in, the cost of maintenance had been £362 per annum, against £510, which had previously been paid for gas, at the rate of 3/2 per thousand feet. That firm had since extended their installation, and at the present time had about 1,600 lamps. With regard to the power which was required for driving dynamos, that was in proportion to the number of lamps in use, that was to say the dynamo, although running at the same speed, only required power proportionally to the number of lamps lighted. As to whether steam, gas, or other engines were the best for driving, that depended very much on circumstances, but perhaps the most economical results were obtained from steam engines. With

regard to electric lighting of railway carriages, he said there had not been very much done, and it was extraordinary that more had not been done. One of the difficulties was that so many of the trains were broken up at different stations. With the same set of carriages running permanently in connection there was no difficulty in lighting them up from a dynamo on the locomotive; but where trains had to be broken up, the carriages might be lighted separately by means of accumulators. This would involve a considerable outlay, and so long as the British public were satisfied with the existing arrangements it was hardly to be expected that railway companies would do much in the matter. As to the introduction of electric miners' lamps, a great many experiments had been made, and the Edison Swan Company had now produced a lamp which weighed only about 6lbs,, which gave a light three to four times the power of the ordinary miner's lamp, besides being much safer, and would burn from 12 to 15 hours. In many collieries the main ways, he said, were lighted up by incandescent lamps, worked from a dynamo at bank.

Mr. Williamson concluded by thanking the members for the kind attention they had given him.

DIAGRAMS.

PLATE 1



nme Dynamo, Elwell-Parker Type.

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PLATE

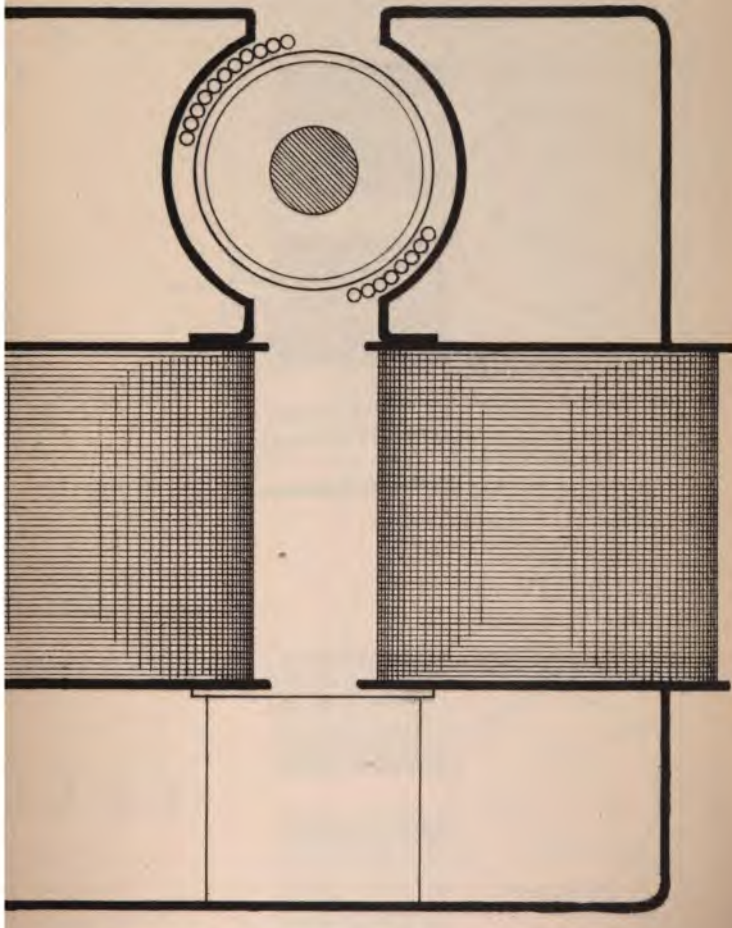

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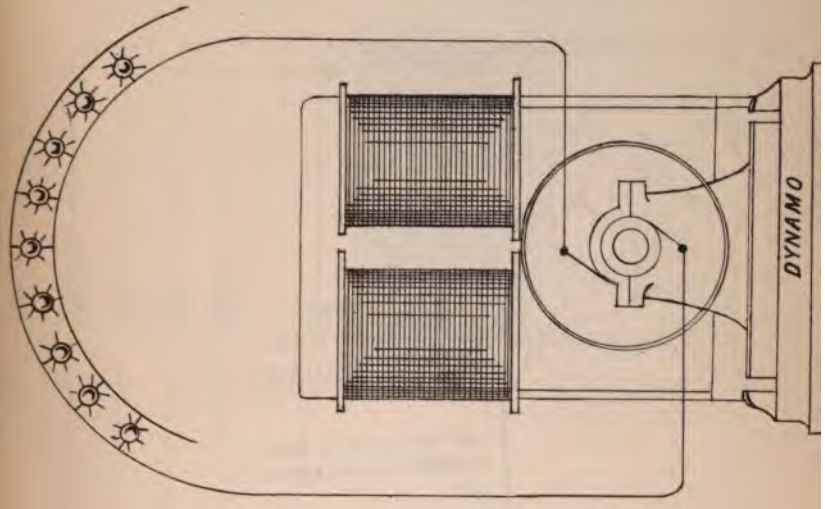
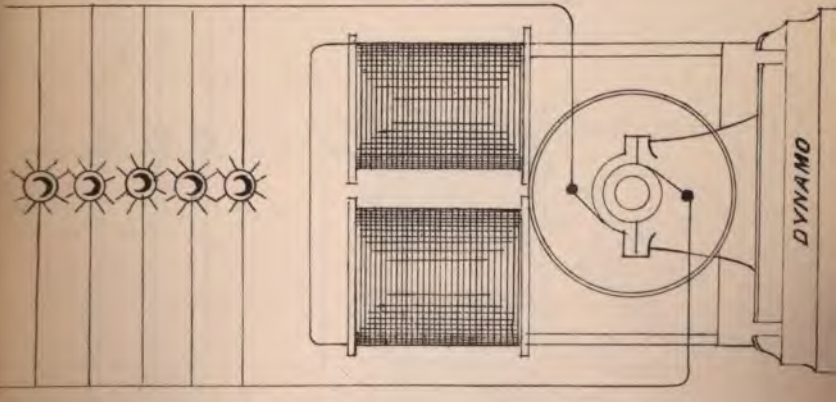
PLATE 3





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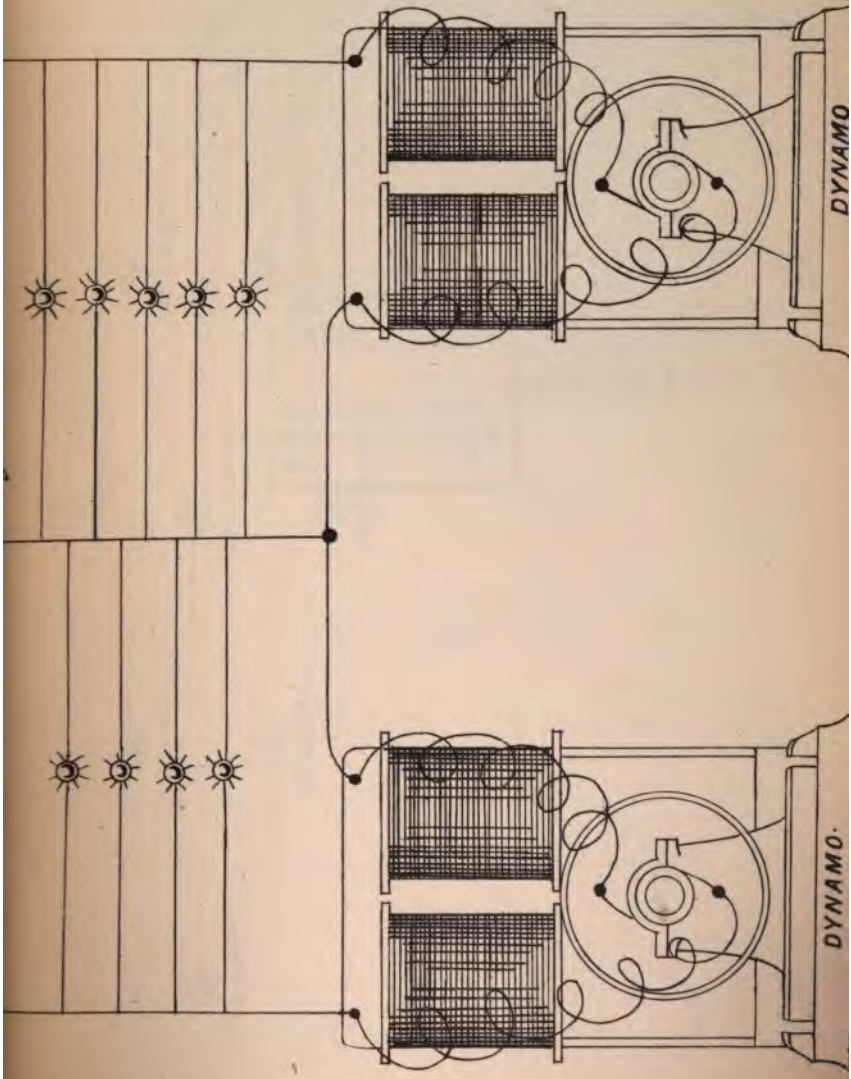

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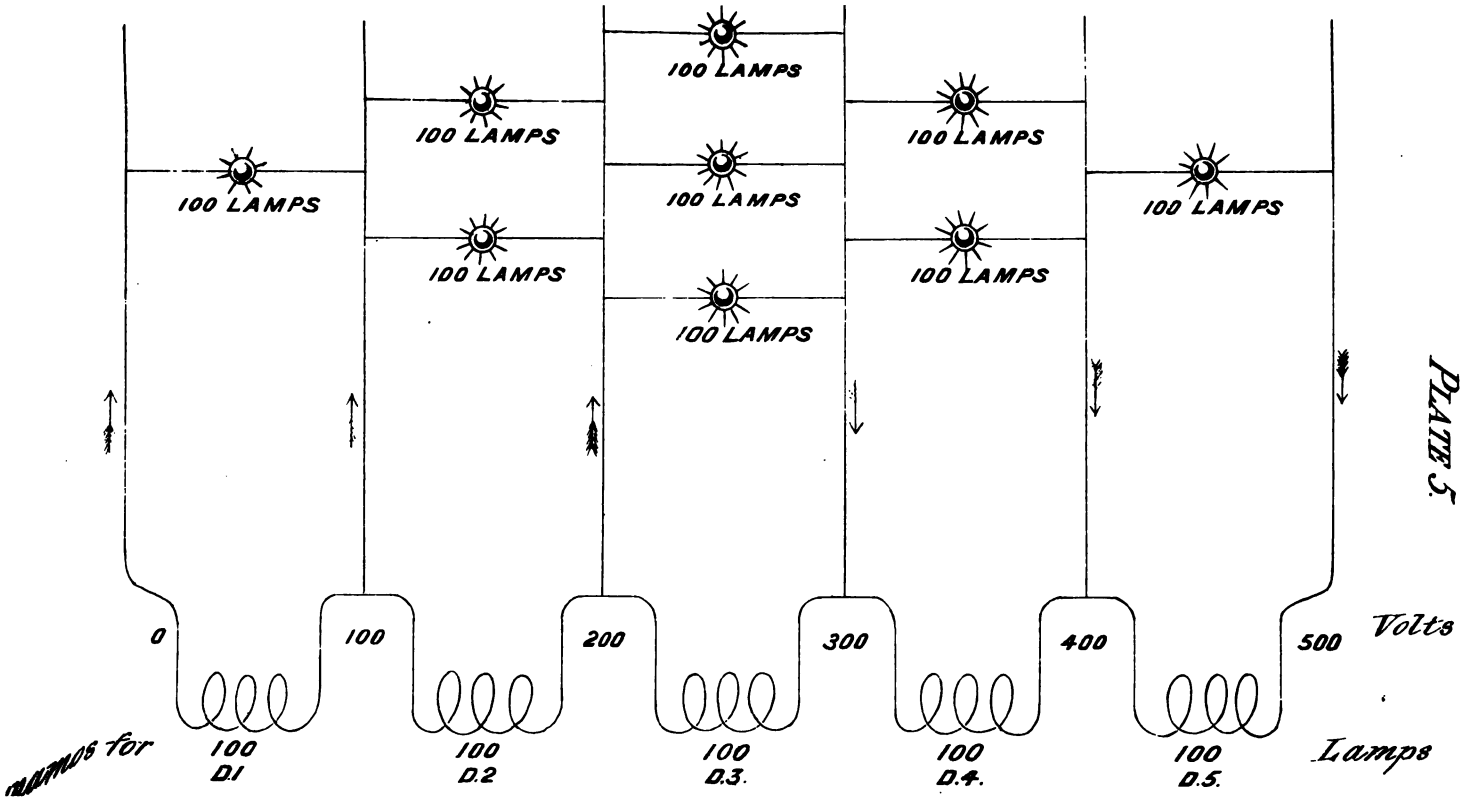
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PLATE 5.

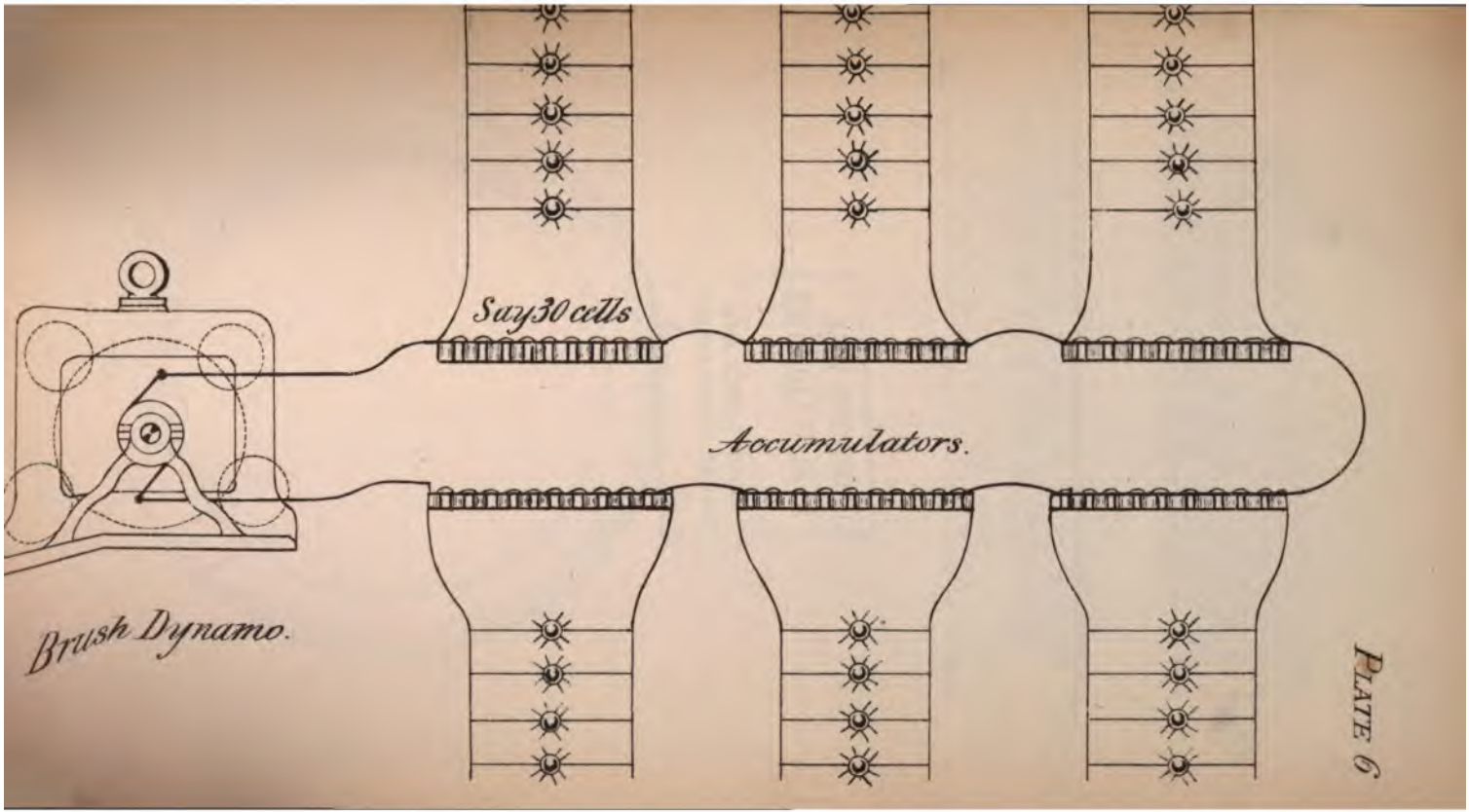

PLATE 6

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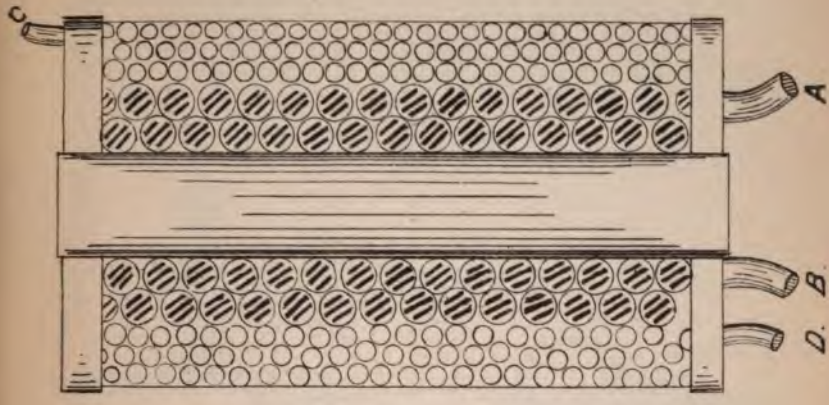
TILDEN FOUNDATIONS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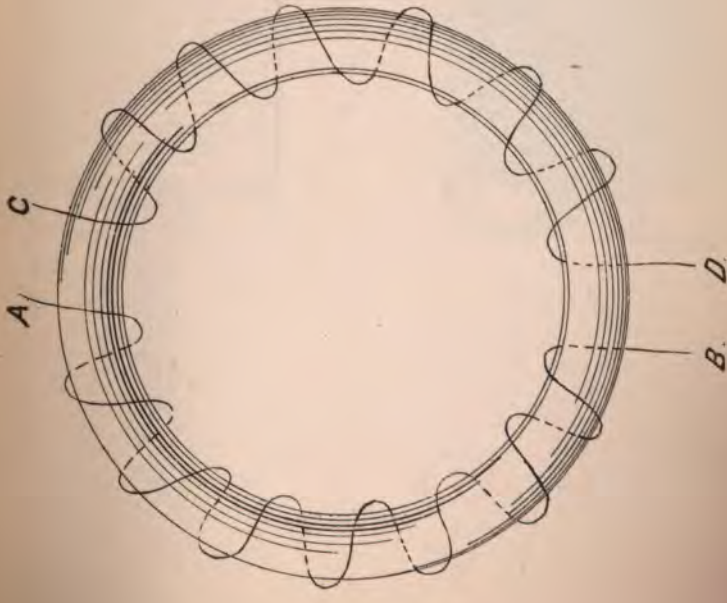
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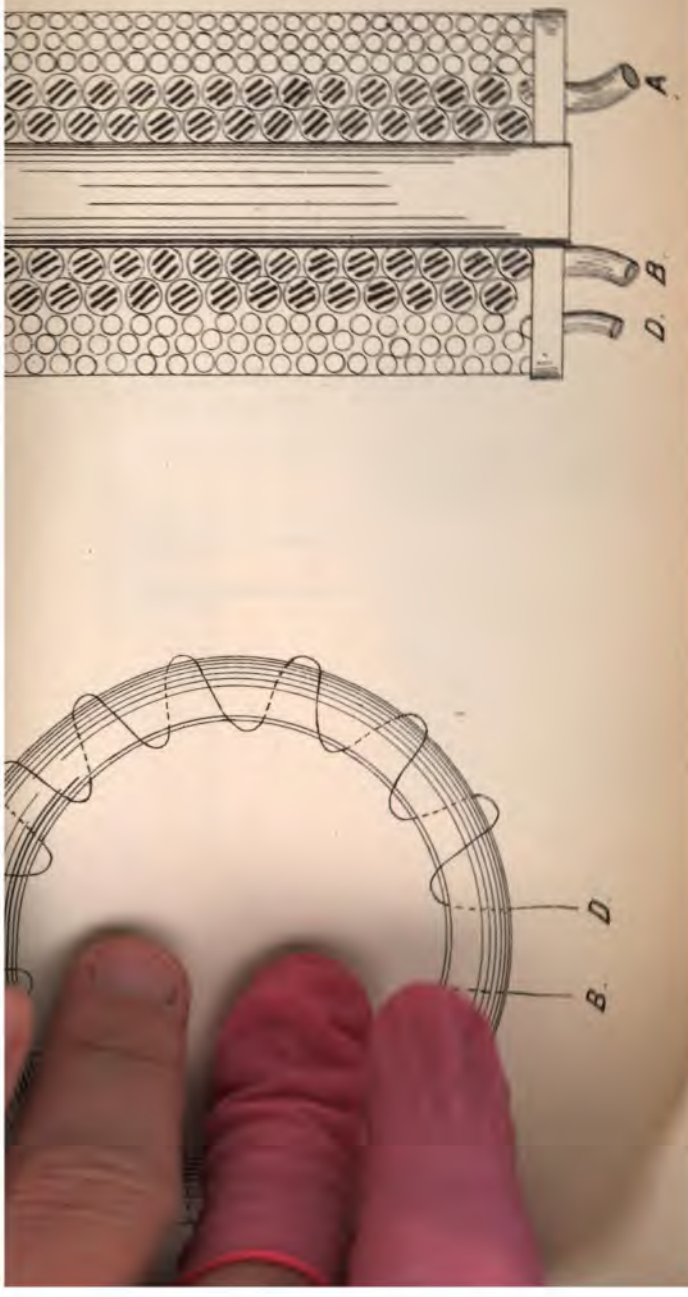

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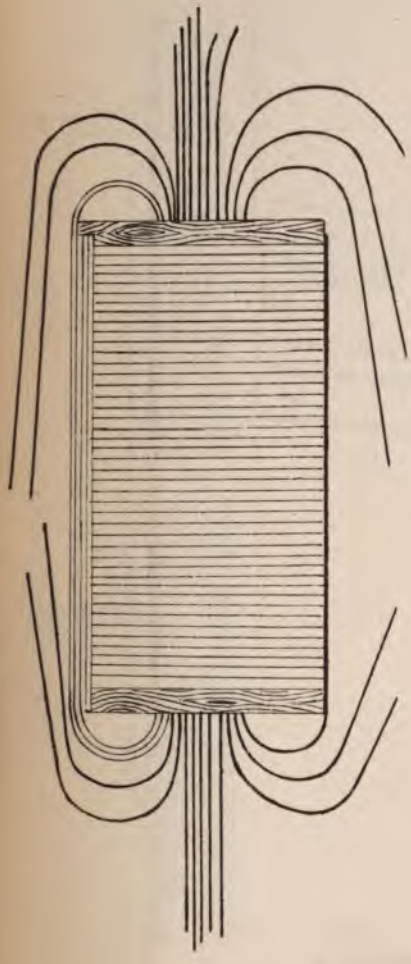
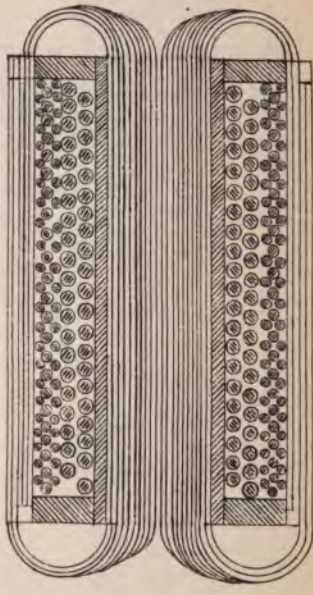
PLATE 8.





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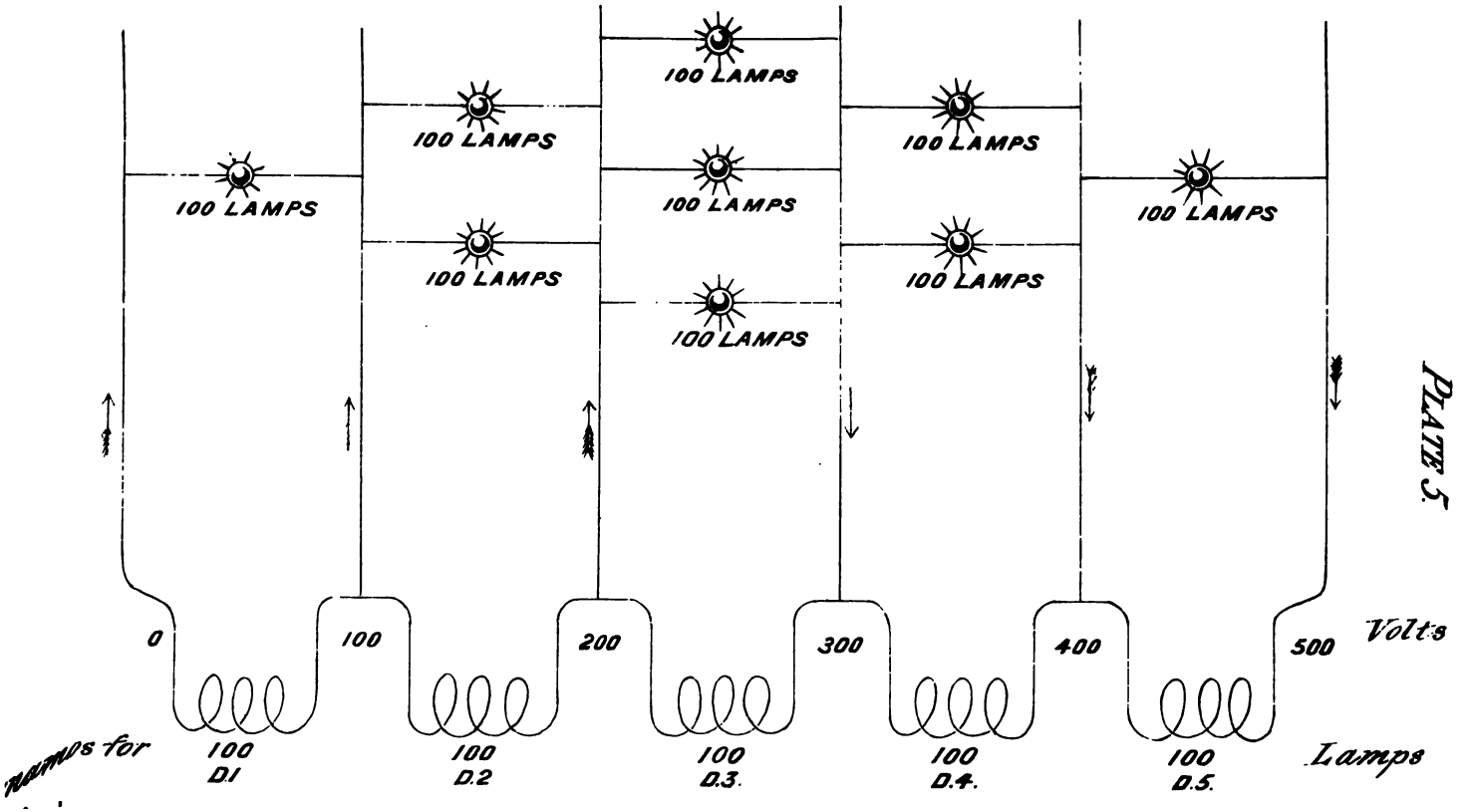
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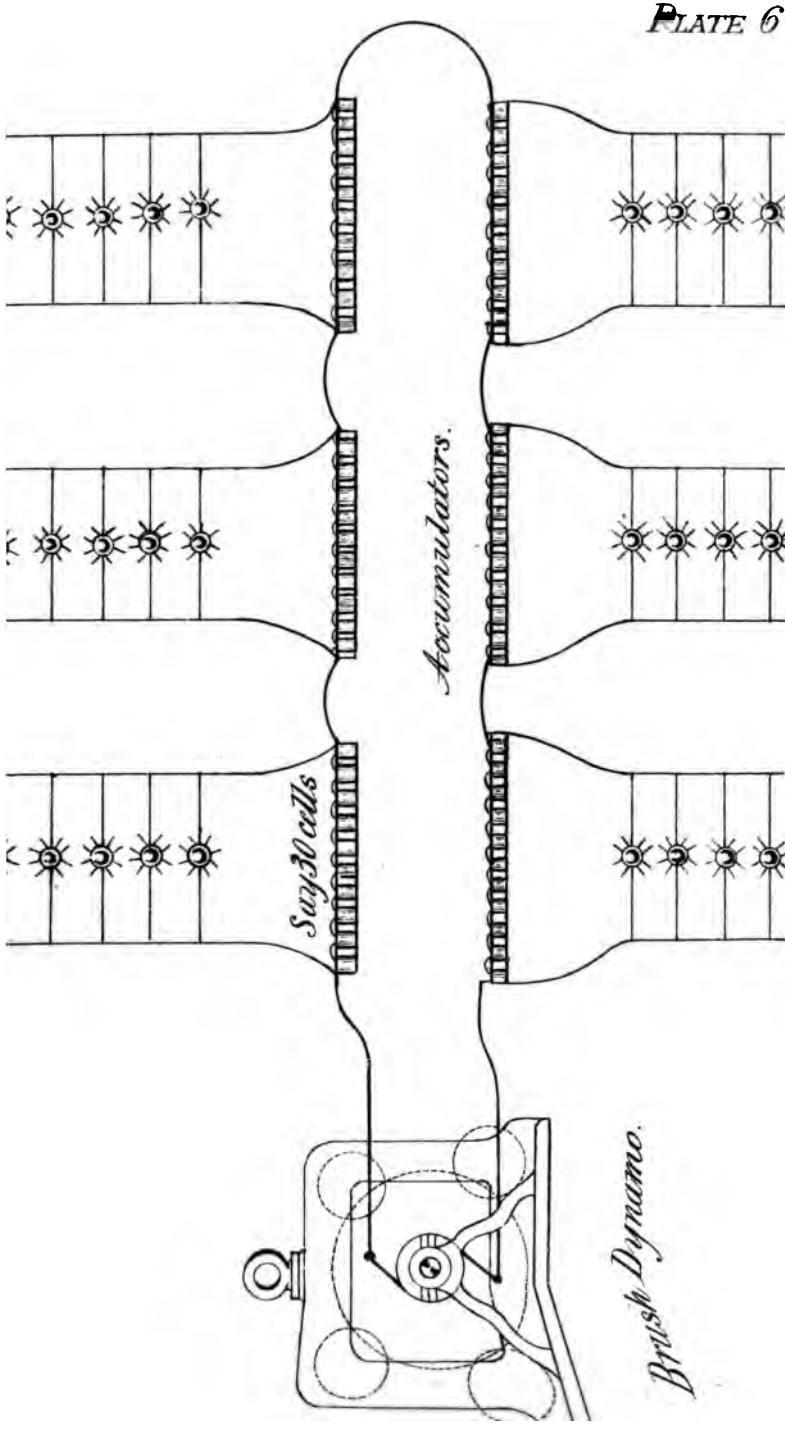
PLATE 5.

PLATE 6



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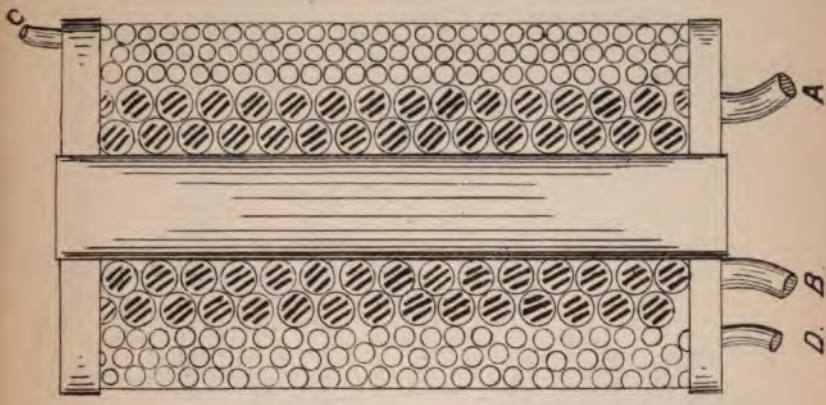
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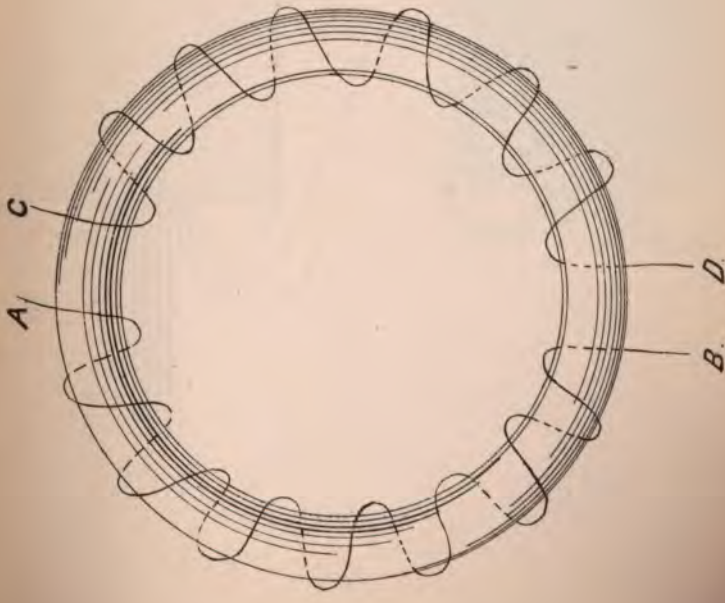
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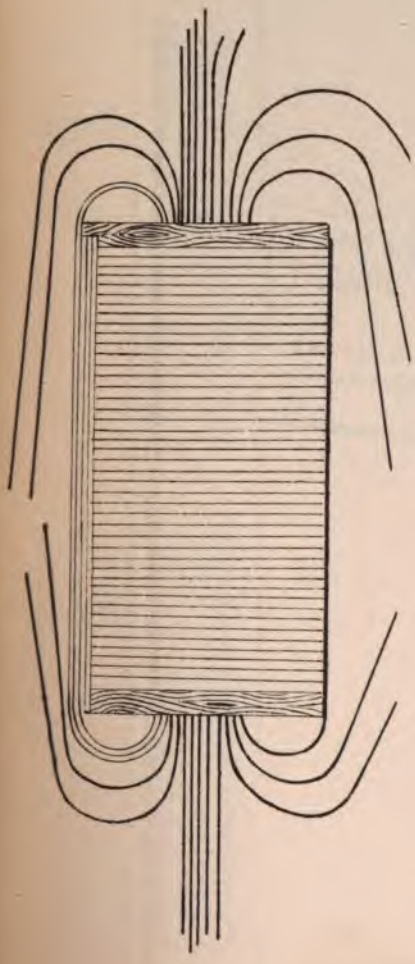
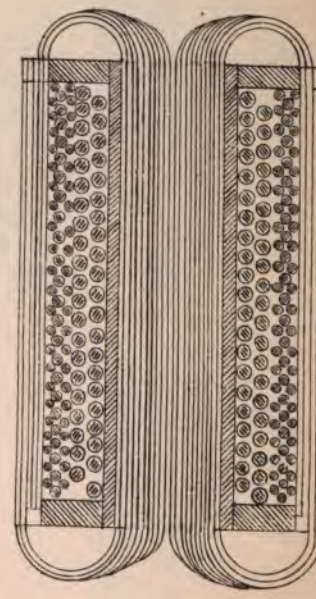
PLATE 8.





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ASTOR, LENOX AND
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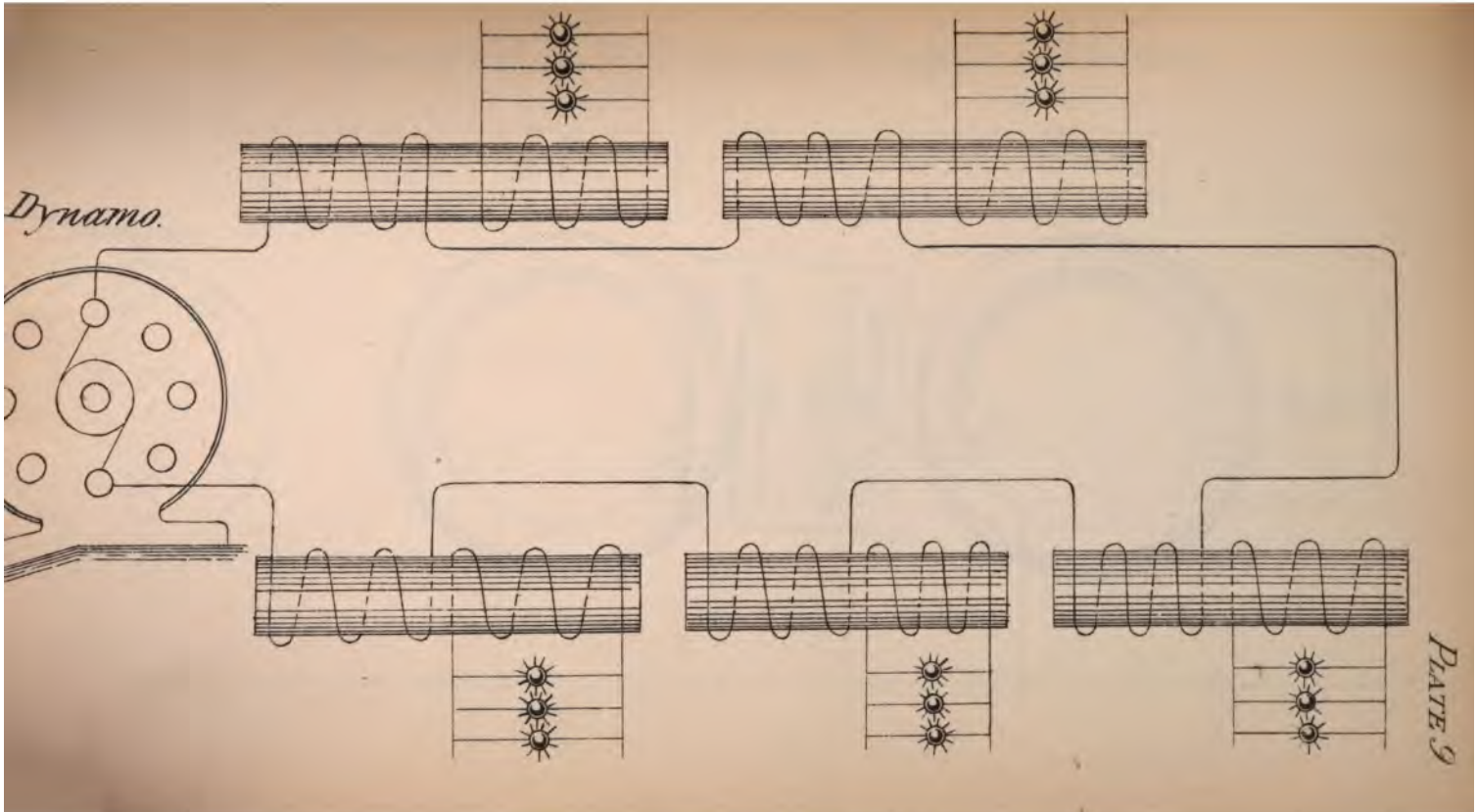

PLATE 9

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Experiment 9

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Plate II

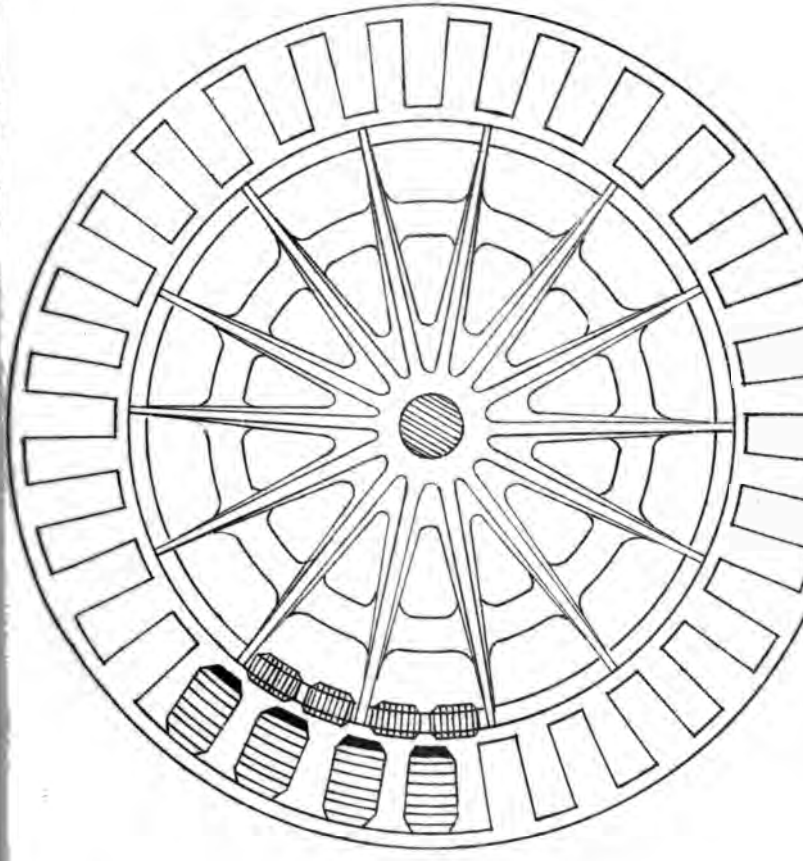

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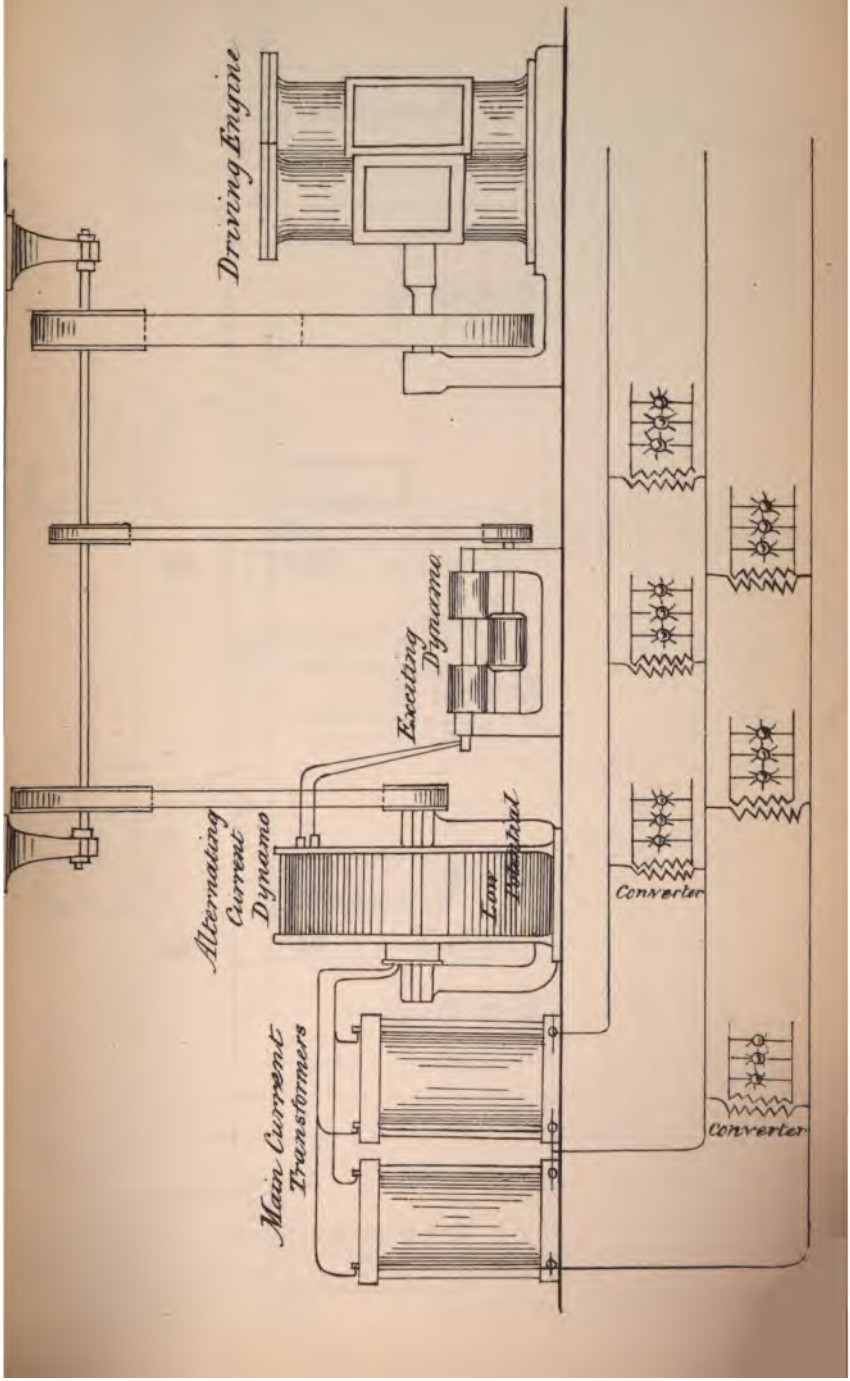
PLATE 12


Driving Engine
Exciting Dynamo
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ASTOR, LENOX AND
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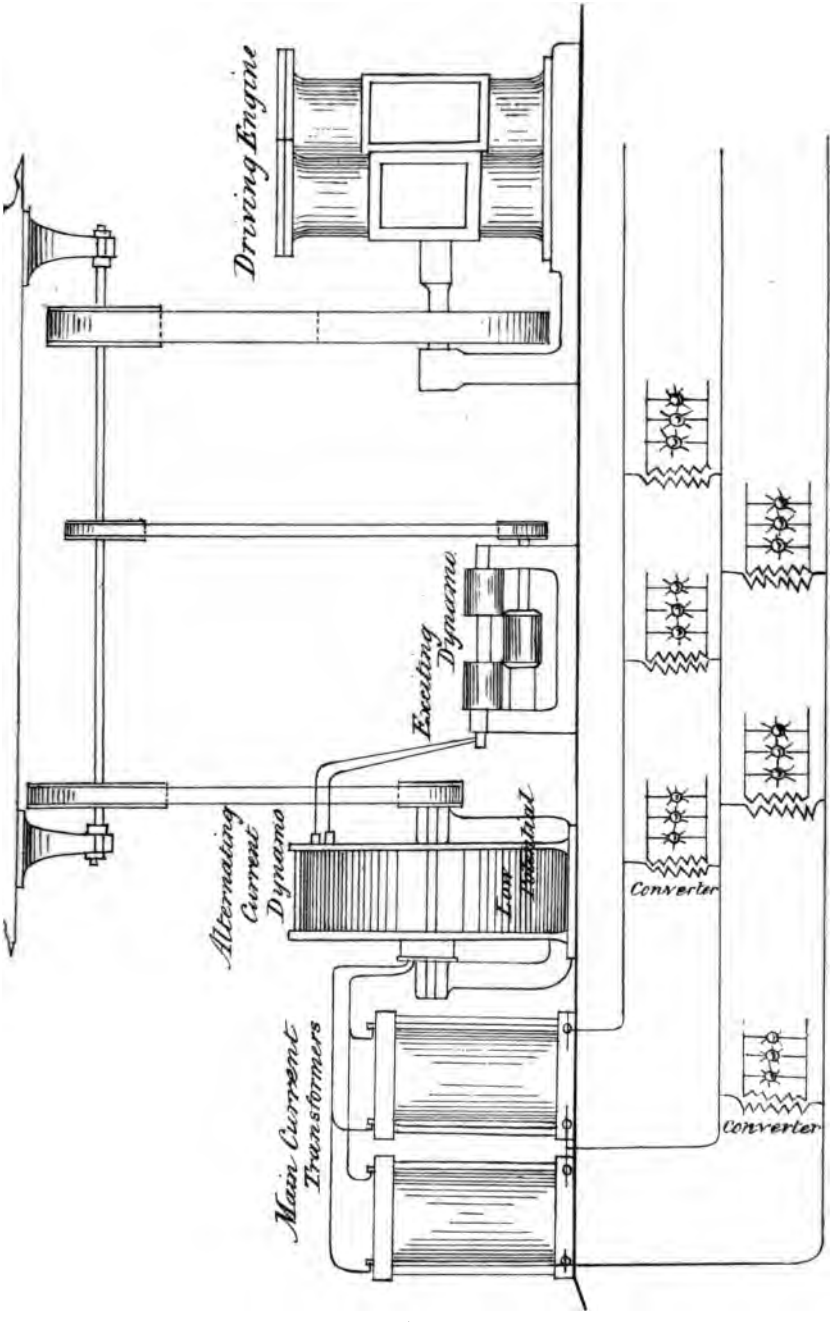
PLATE 12


Driving Engine
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NEW YORK
PUBLIC LIBRARY
ASTOR, LENOX AND
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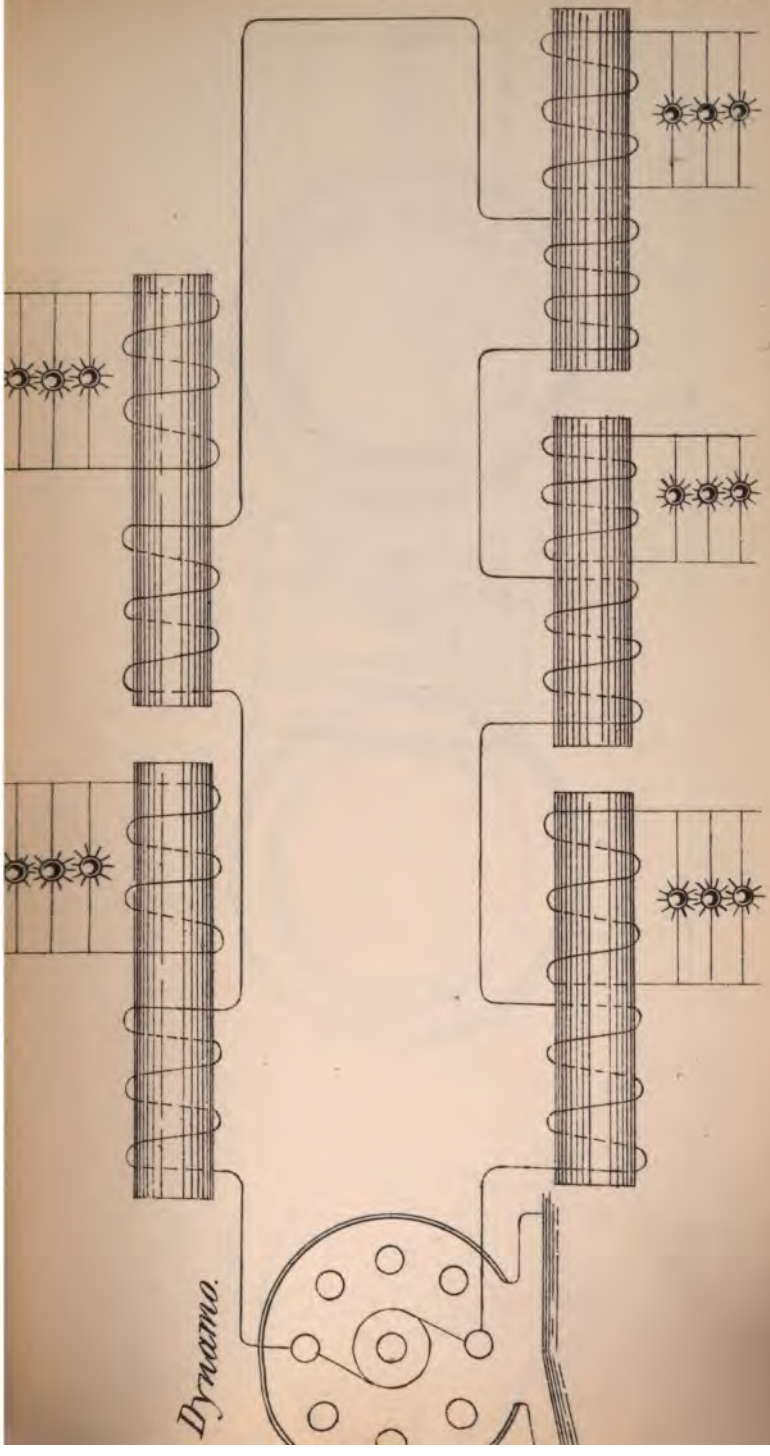
PLATE 9



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Zipernowski & Deri's System of Secondary Generators

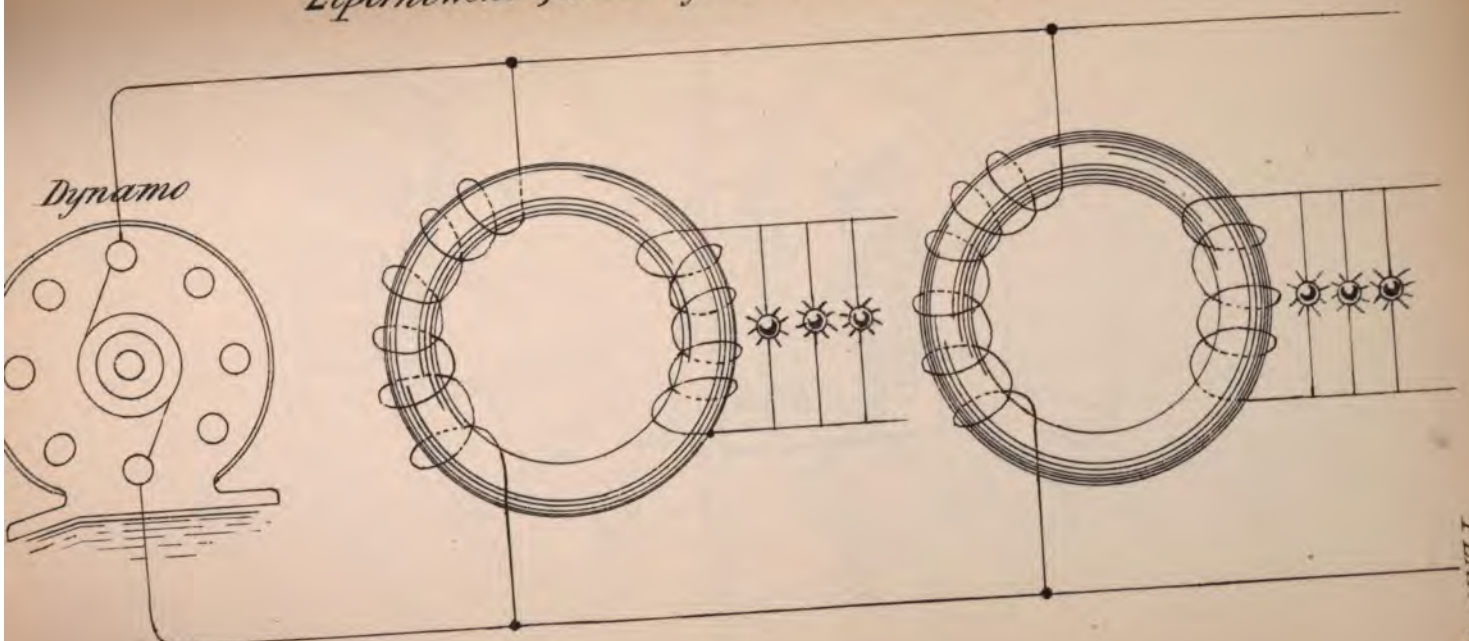

PLATE 10

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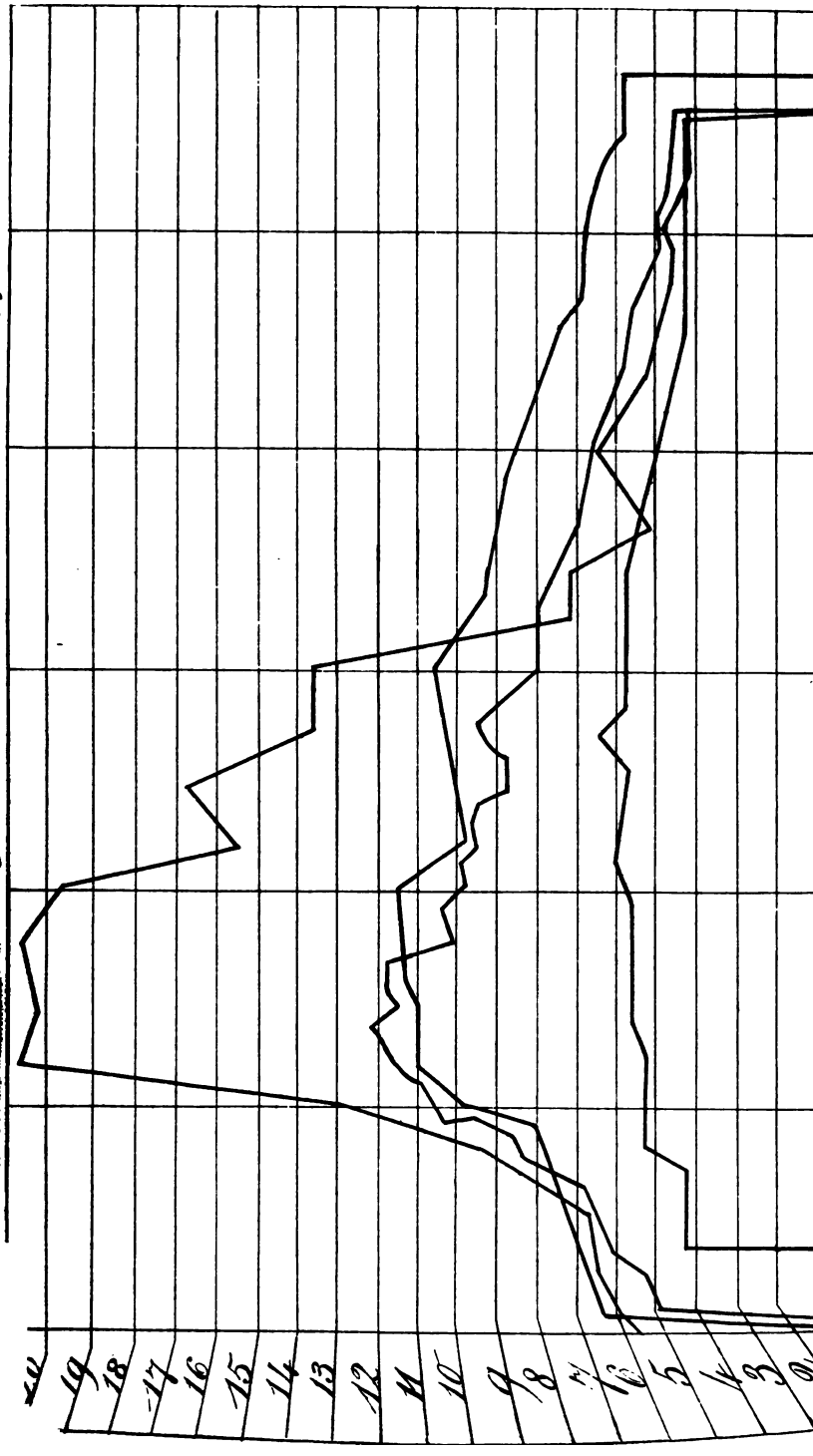
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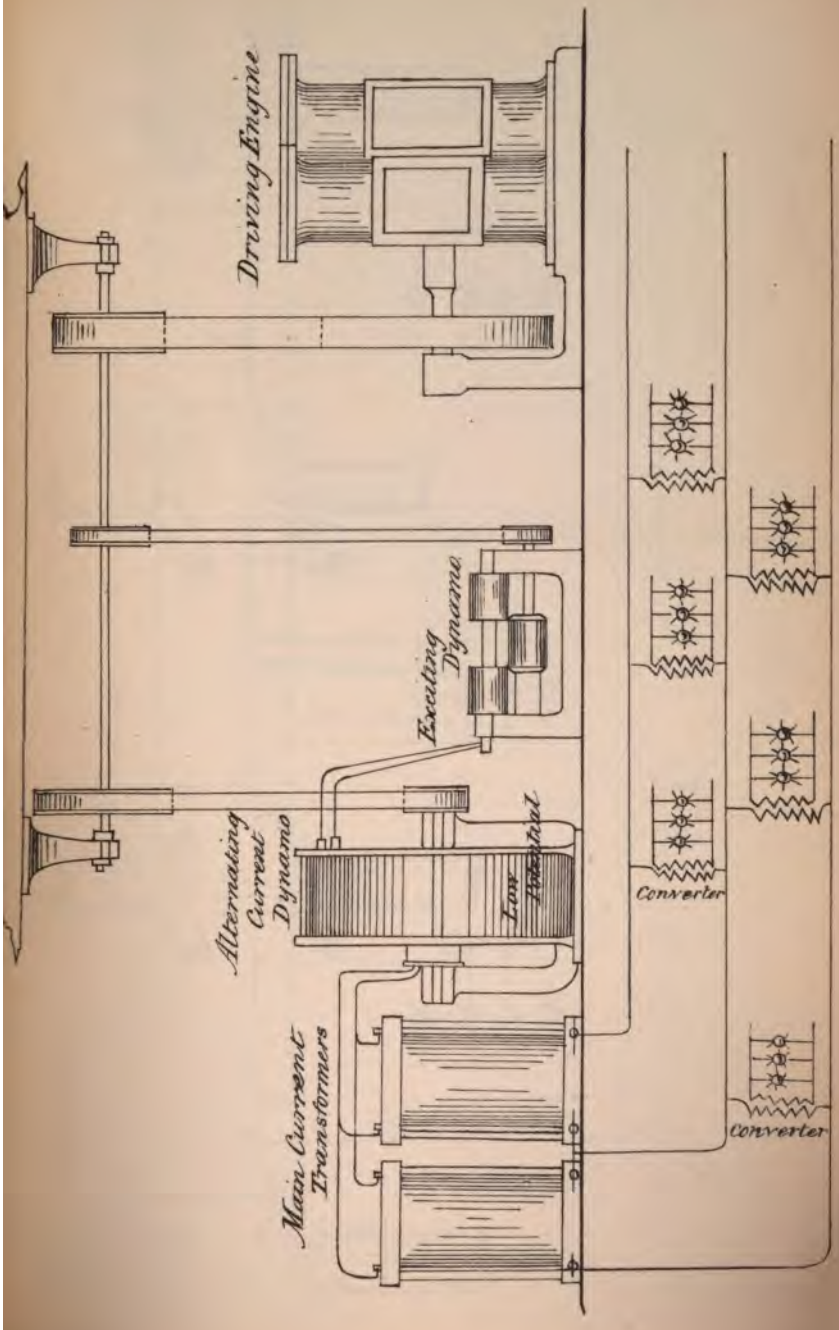
PLATE 12


Driving Engine
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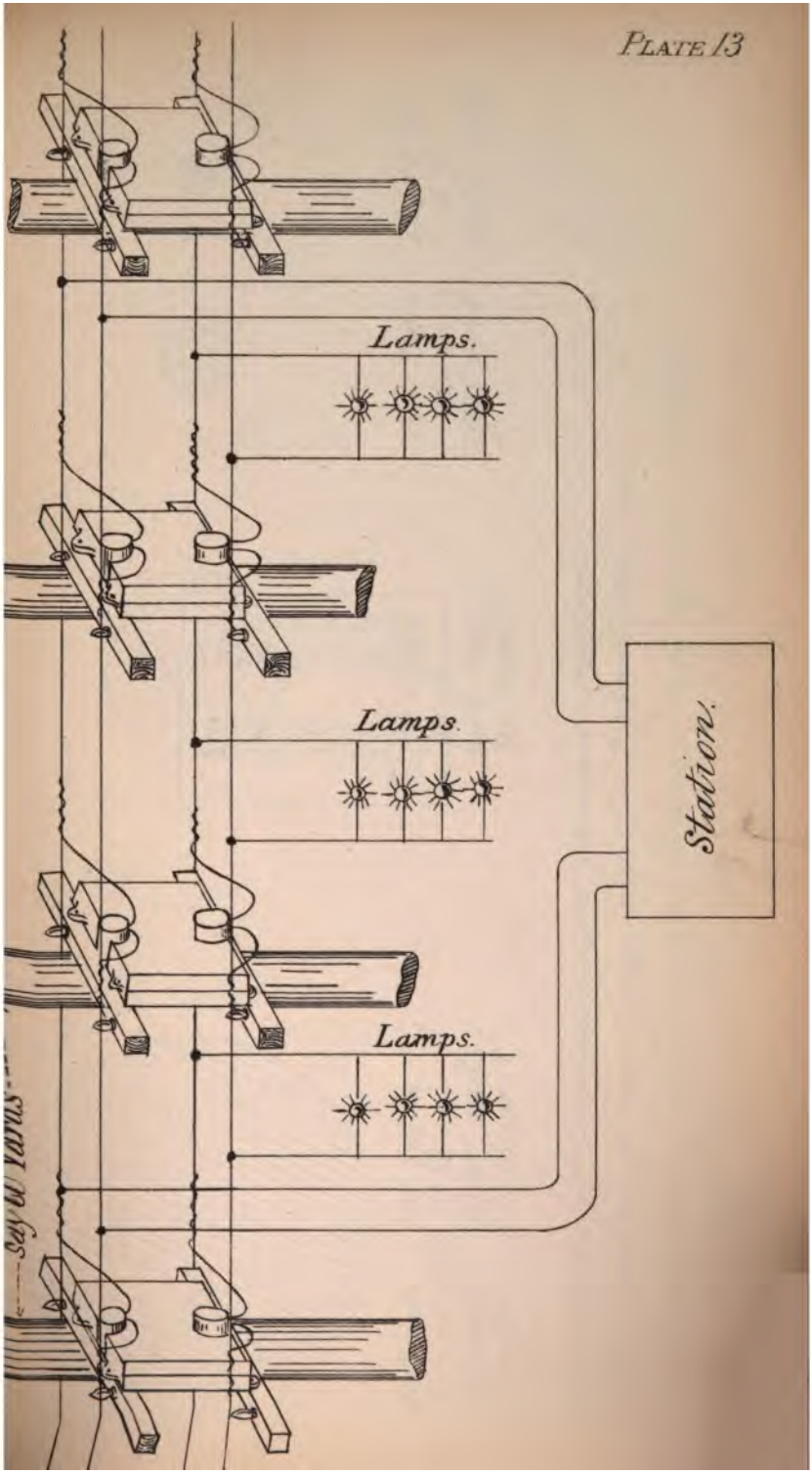
Lamps.
Lamps.
Lamps.
Station.
Sewer Vents

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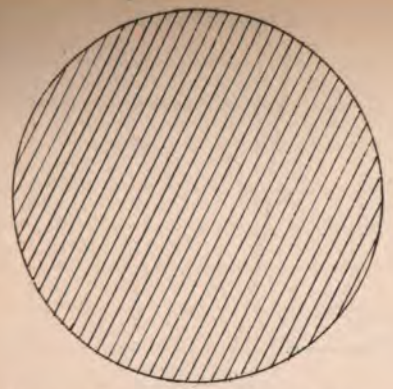

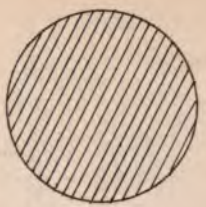

Potential.	100 volts	200 volts	1000 volts	1000 volts.
Loss of ditto	10 %	10 %	2½ %	10 %
Diameter	16000 mils	8000 mils	2908 mils	1454 mils.
Weight	800 lbs per ft.	200 lbs per ft.		

Comparison of Conductors on various Systems.
Cross-section of wire required for 20,000 – 16 c.p.
incandescent Lamps; average distance from dynamo 4000 feet.
Scale 1/8; diagram was full size.

PLATE 14

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32ND Annual Report

OF THE COUNCIL,

1887.

MANCHESTER:

HERALD & WALKER, TYP., BACK POOL FOLD, OFF CHAPEL WALKS.

1888.

OFFICERS.

1888.

President:

MR. SAMUEL DIXON, M. INST. M.E.

Past-President:

MR. ALDERMAN W. H. BAILEY, J.P.

Treasurer:

MR. HENRY MAINWARING.

Trustees:

MR. E. ASQUITH, MR. G. CARTER, MR. R. RAWLINSON,
MR. JAS. WALTHEW, AND MR. T. ASHBURY.

Council:

MR. C. FARMER,	MR. J. HARTLEY,
,, S. BOSWELL.	,, J. HORSLEY,
,, W. TAYLOR,	,, W. LAWSON.

Secretary:

FRED. WALTHEW,
18, Hullard Street, Old Trafford, Manchester.

Assistant Secretary and Librarian:

FRANK HAZELTON,
15, Raglan Street, Hulme.

Annual General Meeting,

HELD AT THE

GRAND HOTEL, MANCHESTER,

10th December, 1887,

Mr. Alderman W. H. BAILEY, J.P., President,

IN THE CHAIR.

THE minutes of the previous meetings having been read and confirmed, and signed by the President,

The Chairman announced to the meeting the result of the ballot for the election of new members.

The election of President and other Officers of the Association was next taken, with the result as set forth on opposite page.

Resolved unanimously,—"That the cordial thanks of this meeting be given to Mr. Alderman W. H. Bailey, J.P., for the deep interest he has taken in the welfare of the Association; for the excellent manner in which he has discharged the duties attaching to the Office of President during the past three years; and especially for the urbanity and tact he has at all times displayed in the chair."

Mr. Bailey returned thanks.

Resolved unanimously,—"That the thanks of the Association are justly due and are presented to the Past-President and other Officers of the Association for their co-operation with the President, and for their zeal on behalf of the Association during the past year."

Messrs. Asquith and Mainwaring returned thanks.

Resolved unanimously,—"That the Annual Dinner be held as usual; all arrangements to be left in the hands of the Council."

ANNUAL REPORT OF COUNCIL.

1887.

The Council have much pleasure in congratulating the Members on this occasion of the 32nd Anniversary Meeting of the Association upon its satisfactory position, the increase in the number of Members, and the successful progress and advancement of the Association during the past year.

To the membership roll during the year have been added—

16 Honorary Annual Members.
15 Ordinary Members.
—
Total 31

but taking into account the loss by death, resignation, and erasure, the effective addition to the membership roll amounts to 17, bringing up the total number of names of all classes on the roll to 316, namely :—

26 Honorary Life Members.
82 Honorary Annual ,,
208 Ordinary ,,

Upon reference to the Financial Statement as certified by the auditors (see appendix), it will be seen that the balance standing to the credit of the Association amounts to £2,568 1s. 3d. after payment of all accounts due up to the 31st December, and after deducting the sum of £150 loss on investment in the British Building Society. But for this unfortunate loss the year's working would have shown the very handsome balance of £90 11s. 4d. notwithstanding the decreased income from investments in building societies, and that the sum of £50 has been paid as funeral allowance on behalf of deceased members. Owing to the number of members who have claimed and been awarded Superannuation Allowance, it has only been possible to pay to each superannuant the sum of 5s. per week. The Council desire that this small allowance should be augmented, and the co-operation of the members and friends of the Association in this direction is again respectfully solicited.

It is with profound regret the Council have to record that during the year death has removed the following Members, memoirs of whom are appended on pages 272 to 277. In accordance with resolutions, letters of condolence and sympathy have been forwarded to the widows and families of the deceased members :—

Ayton, J. S. - - -	Rochdale.
Burton, John - - -	Manchester.
Clarke, Robert - - -	,,
Curtis, Matthew - - -	,,
Furnevall, John - - -	Haslingden.
Fletcher, E. - - -	Salford.
Griffiths, Wm. - - -	Manchester.
Heywood, Wm. - - -	,,
Moran, James - - -	,,
Saxon, John - - -	,,

The following gentlemen have resigned their Membership in the Association during the past year :—

Summers, H. - - -	Stalybridge.
Waldenström, E. H. - -	Manchester.

The following gentlemen have ceased to be Members of the Association during the past year :—

Barker, Fred. - - -	Manchester.
Chester, W. R. - - -	,,
Daltry, T. L. - - -	,,
Mant, G. - - - -	Handsworth.
Taylor, Robert - - -	Manchester.

The Council have great pleasure in referring to the increased number and practical importance of the papers that have been presented to the Association during the past year, and take this opportunity of expressing their thanks to the authors of the papers for the valuable information they have thereby furnished to the Association. The Council confidently anticipate a continued advancement in the importance and number of the communications to be brought before the Association, and they trust that all the Members will aid, as far as they have the opportunity, in advancing the objects of the Association by contributing papers on Engineering subjects that have come under their observation and investigation, and communicating the particulars of executed works, with the results of their actical working, whether successful or unfavourable, that may viceable and interesting to the members.

PAPERS READ DURING THE SESSION.

15th Jan.—On "**The Chief Mechanical Inventors of Lancashire.**" Inaugural Address by the President, Mr. Alderman W. H. Bailey, J.P., of Salford.

29th Jan.—On "**The Thermo Dynamic Analysis of the Steam Engine,**" by Mr. Herbert Guthrie, of Manchester.

* 26th Feb.—On "**Continuous Pneumatic Railway Brakes,**" by Mr. George Kiernan, of Manchester.

12th Mar.—On "**The Conservation of Energy,**" by Mr. Samuel Dixon, M. Inst. M.E., of Marple.

† 26th Mar.—On "**Indicator Diagrams,**" by Mr. James Hartley, of Manchester.

‡ 16th July—On "**The Victorian Triumphs,**" by Mr. Alderman W. H. Bailey, J.P., of Salford.

15th Oct.—On "**Steam Boiler Legislation.**" Opening Address by the President, Mr. Alderman W. H. Bailey, J.P., of Salford.

§ 22nd Oct.—On "**Material Used in Boiler Construction,**" by Mr. Samuel Boswell, of Manchester.

22nd Oct.—On "**Locomotive Engines,**" by Mr. Thomas Ashbury, C.E., of Manchester.

22nd Oct.—On "**Pipes for the Thirlmere and Bombay Water Works,**" by Mr. J. Horsley, of Manchester.

22nd Oct.—On "**Knop's Turbine,**" by Mr. J. Ingleby, of Manchester.

22nd Oct.—On "**Ammonia Still and Process of Manufacturing Sulphate of Ammonia,**" by Mr. W. Schroller, of Manchester.

22nd Oct.—On "**Coke Oven and Ammonia Still,**" by Mr. W. Schroller, of Manchester.

22nd Oct.—On "**The Four Engines Turning Machinery at the Manchester Exhibition,**" by Mr. R. Sugden, of Salford.

12th Nov.—On "**The Modern Cotton Carding Engine,**" by Mr. Joseph Nasmith, of Manchester.

26th Nov.—On "**Electric Lighting from Central Stations,**" by Mr. J. R. Williamson, M.S.T.E., of Manchester.

All the above papers have been published in transaction form, together with the discussion thereon, and issued to the members.

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* By the kindness of Messrs. Gresham and Craven, the members were granted the privilege of inspecting at the Craven Works, Salford, a full size working model of the Gresham Vacuum Automatic Brake Apparatus, prior to the reading of the paper.

† This paper was illustrated by upwards of 100 diagrams, photographed upon glass, and thrown upon a screen by the aid of the Oxy-Hydrogen Light.

‡ Delivered in the Palm House Dining Room, on the occasion of the Association's visit to the Royal Jubilee Exhibition, Manchester.

§ All the papers read on this date had reference to exhibits in the Royal Jubilee Exhibition, Manchester.

It is gratifying for the Council to record that during the year there has been a steady increase in the attendance of Members at the meetings of the Association. The average attendance during the sessional meetings has been 90, and during the summer months 30.

The Thirty-first Anniversary Meeting and Dinner took place on Saturday the 12th February, at the Grand Hotel, Manchester, on which occasion the Chair was very ably filled by the President of the Association, Mr. Alderman W. H. Bailey, J.P., and the Vice-Chair by Mr. Thomas Ashbury, C.E., Past-President. The chief guest of the evening was Sir Joseph C. Lee, J.P., Chairman of the Executive Committee of the Royal Jubilee Exhibition, Manchester. 135 Members and friends were present.

Sir. J. C. Lee, in proposing the toast of the evening, "Prosperity to the Association," said he thought the report which had been read augured a great measure of success. It seemed to him that the Association was founded somewhat upon the lines of those old guilds which were instituted in this country somewhere about the 13th century. The success, however, that would attend the modern Association would be far above anything that had been accorded to the old guilds, because it is on a far more liberal and firm basis. The old guilds were suppressed because they placed themselves as a barrier against improvement. That Association, by its rules, assisted any engineer, or anyone connected with the engineering trade, in the development of any new invention. That he thought would be the salvation of their Association, inasmuch as it formed a basis which would commend itself to every intelligent mind. Speaking to them as a merchant of long standing and having an intimate connection with manufacturing, he thought the mechanical engineer, to many manufacturers and merchants, was to be considered as a man who destroyed assets, and who was the cause of the shrinkage of capital and of all those things which went to make the assets of a manufacturing concern. To those who did not use the best appliances he was certainly a great bugbear, but to those who looked ahead and accepted the new inventions which were constantly being brought forward

he was a source of great strength, as he enabled the manufacturing portion of the community to compete against the most absurd tariffs of other countries. The mechanical engineer built upon other men's inventions. It was so in design, it was so in art, and it was so in everything—they built upon and developed that which had gone before. The mechanical engineer had made havoc amongst those who did not move quick enough for him —(Hear, hear.) He could not think of that Association without referring for a moment or two to a great enterprise which seemed to be in some way or other in his mind connected with the Society of Engineers—he meant the great project of the Ship Canal. (Applause). That great scheme seemed to him inseparably associated with the name of one of their members—the name of the Ship Canal and the name of Adamson seemed to be almost synonymous terms. (Hear, hear.) The carrying out of that work would prove to be a new departure for the engineering trade of this district. He thought their Association was perhaps formed on a little too narrow basis, and that if they could in some way become connected with the merchant class, so that they might be brought into contact with them, probably some good might come of it.

The Chairman responded on behalf of the Association. He said he was sure he was only expressing the feelings of the members when he said how thankful they were to Sir. J. C. Lee not only for honouring them with his presence, but also for the very original remarks he had made on engineering industry in proposing success to the Association. (Hear, hear.) Sir Joseph was one of the most hard-working men in Manchester in connection with movements intending to promote the welfare of the community. (Hear, hear.) He (the chairman) believed there was still a great future before the mechanical industry of this country, for it had been shown conclusively by a recent writer that even if we paid double the wages paid on the Continent, we could still afford to undersell continental manufacturers. So that if we could only have peace in Europe we might expect great prosperity for the engineering and other industries.—(Applause).

Professor Thomson proposed "The Engineering Industries." He said that almost everything they looked upon in this world

seemed to be associated with the engineer, and the latter seemed to be a man whose duty was to harness the rays of the sun and produce thereby a certain amount of energy in whatever direction he wished, for they were told that all energy they possessed came from the rays of the sun, and the energy which engineers knew so well how to economise was that which was produced from the coalfields of Great Britain. (Hear, hear.) He had been told that the success of the Suez Canal was not so much due to the ability of the great canal engineer as to that of the engineers in the marine service who had produced engines which would enable ships to be brought through the canal from China and India with a smaller amount of coal than had previously been carried. But for the invention of those engines the Suez Canal would have been practically useless. The science of engineering was so wrought up with everything they possessed that he had great pleasure in proposing "Success to the Engineering Industries in the future."

Mr. E. Leader Williams, C.E., responded. Replying to the remarks of Professor Thomson as to the Suez Canal, he said that no improvement in marine engines could have driven the steamers to which he referred across the sands of Arabia if the Canal had not been made. With regard to the Manchester Ship Canal, he said it was a pleasure to feel that if it could be carried out, it would open up additional industries in this neighbourhood, not the least of which would probably be that of marine engineering. (Applause.) He was glad that Sir J. C. Lee, Mr. Charles Moseley, and others, had joined the board, and he hoped to be able some day to show the Members of this Association over the Ship Canal works. (Applause.)

Mr. Thomas Ashbury proposed "Success to the Royal Jubilee Exhibition," coupled with the name of Sir J. C. Lee, Chairman of the Executive Committee. He said Manchester and the surrounding district were about to celebrate the Jubilee of Her Majesty's Reign in a more distinct and practical form than any other part of her dominions. In that Exhibition would be gathered together samples of work executed in this district during the last 50 years, and which would show a development of invention and mechanical skill that the world had never seen equalled.

Sir J. C. Lee, in responding, said he thought the Exhibition would be the most extraordinary one that had ever been held in this country. The section in which those present were most particularly interested—that of mechanical engineering—would not be the least extraordinary part of it. There would be seen in the Exhibition the development of the very first principles of the spinning manufacture to the perfection at which it had arrived at the present day. The development of machinery in this country had been so extraordinary during the last few years that he was almost afraid to tell them what was the state of things many years ago; but he calculated from his grandfather's books, which he had taken possession of, that in 1784 the speed of a loom was from 17 to 20 "picks" a minute, whereas at the present time they were working at the rate of 220 "picks" a minute. The same improvement was manifest in calico printing. For all those changes they had to thank the mechanical engineer, who had made England what it was to-day. (Hear, hear.) Another very important section in the Exhibition would be that of industrial design. As they would know, if we had a failing in this country it was in design. We had been expected to go to France, and we were now constantly going there, to get ideas drawn and executed. He hoped that by means of the Manchester School of Art, and the Technical School they would before long create such a change as that Englishmen would print and manufacture English designs. He trusted before long that we should have a class of designers in Manchester second to none in the world. (Hear, hear.) There was then the handicraft section, and he trusted something would be shown in that section which would be the means of enabling cottagers to earn a livelihood by the production of artistic work. The fine art section, under the presidency of Mr. W. Agnew, would without doubt be the finest display of modern art that had ever been shown in England. There was the electrical section, under the rule of Mr. C. Moseley; and another section which he was sure they were right in organizing was the Irish section. (Hear, hear.) The Committee offered a friendly hand to Ireland and asked her to bring her best productions, and they extended to Ireland every facility for exhibiting. "Old Manchester" would be a most interesting attraction, as would be also the

section of chemical industry. What, however, was to be the end of it all? He thought that the Exhibition building which had been put up at such enormous expense should be preserved. (Hear, hear.) They had no museum of mechanical engineering, and there was plenty of space for such a thing when the Exhibition was concluded. Manchester had no musuem of the textile industry, and in fact no museum at all, and so long as we were without museums we were placed at a considerable disadvantage. Nearly every manufacturing town on the Continent had its local museum, where the workpeople had free entrance and could study all kinds of machinery by way of models. He trusted before the Exhibition was closed some plan would be formed by which the buildings could be retained on the present site, for use as a means of instruction for the engineers and manufacturers who would follow after them. (Applause.)

The toast of "Kindred Associations," proposed by Mr. Joseph Nasmith, was responded to by representatives from London, Leeds, Newcastle, and Middlesborough Associations.

Contrary to the usual practice for some years past, the Council are not able to report any special Engineering Excursion during the past year, as it was found that with so magnificent and unique a collection of productions as was gathered in our city under the designation of "The Royal Jubilee Exhibition," there was ample opportunity afforded to the members of leisurely and with personal comfort, seeing and studying under the most favourable conditions the most advanced and perfect examples of British industry—many in actual operation—and revealing the marvellous growth and development of art and science, and the almost miraculous progress of the chemical, industrial, and engineering industries of this country during the Victorian Era.

The Association, in a formal manner, was invited by the President (himself one of the chairmen of sections) to visit the Exhibition, and on Saturday the 16th July, he and Mrs. Bailey received upwards of 150 Members in Ancoats Old Hall. Having extended to the Members a hearty welcome to the Exhibition, they were subsequently entertained by Alderman

and Mrs. Bailey to a sumptuous tea in the Palm House dining-room, after which the President delivered a very interesting address on "The Victorian Triumphs." (See proceedings, page 130.) At the close of the address Mr. Thomas Ashbury (Past-President) proposed in graceful and appropriate terms the thanks of the Members to Alderman and Mrs. Bailey for their hospitality; the resolution was heartily seconded by Mr. R. Rawlinson and supported by Mr. Denny Lane, of Cork, and carried by acclamation. The party afterwards visited the various sections of the Exhibition.

During the past year Manchester has lost one of the greatest mechanicians and most famous ordnance manufacturer of this era, by the death of the late Sir Joseph Whitworth, Bart., and although not a member himself of our Association, yet he was closely connected with it by his partners and staff, and therefore at a meeting held on the 29th January, the following resolution received the unanimous approval of the Members on the proposal of the Past-President, Mr. Thomas Ashbury (who presided), seconded by Mr. R. Rawlinson :—

"That this meeting of the Manchester Association of Engineers, whilst regretting to hear of the death of Sir Joseph Whitworth, Bart., feels it an honour to place on record its high and keen appreciation of the invaluable and distinguished services and benefits rendered by him during the course of a long and eminently active life in promoting the advancement of the practice and teaching of mechanical science, and who by his great ability and skill achieved the grand result of laying down a fundamental basis of truth, accuracy and reliability upon which has been founded unparalled success in the construction of ordnance and engineering and mechanical structures. This meeting also gratefully acknowledges the great impetus given to technical education by the noble generosity and patriotism of one of the most illustrious and honoured citizens of Manchester, whose name is indelibly stamped as the prince of mechanicians, and the originator of absolute accuracy and system in mechanical construction, and wishes to convey to Lady Whitworth deep sympathy in the great loss she has sustained."

LIBRARY.

The Council are pleased to report that the Library continues to fill a very important place in the Proceedings of the Association. The number of books issued during the year has been in advance of that of any previous year. The following new books have been purchased:—

Aluminum. Richards.
History of Prices. Mulhall.
Manual of Lubrication. Simpson.
Modern Machine Shop Practice. 2 vols. Rose.
Natural Philosophy. Ganot.
On the Conversion of Heat into Work. Anderson, W.
Railway Problems. Jeans.
Steam Engine. Holmes.
Treatise on Petroleum. Crew.

The Council have pleasure in acknowledging the following donations, and in expressing their thanks to the donors for the valuable and acceptable additions they have thereby made to the Library:—

American Institute of Mining Engineers. Transactions, 1887.
British Association for the Advancement of Science. Programme, Handbook, and Excursions; Manchester Meeting.
Canadian Institute, Toronto. Transactions, 1887.
Civil and Mechanical Engineers' Society. ,, 1887.
Cleveland Iron Trade Foreman's Association. Annual Report, 1886.
Franklin Institute, America. Journal, 1887.
Institute of Civil Engineers of Ireland. Transactions, 1886.
Institution of Engineers and Shipbuilders in Scotland. Transactions, 1887.
,, Mechanical Engineers. ,, 1887.
Iron and Steel Institute. ,, 1887.
Liverpool Engineering Society. Annual Report, &c., 1886.
Liverpool Geological Society. Transactions, 1886.
London Association of Foremen Engineers. Annual Report, 1887.
Manchester Association of Engineers. Transactions, 1887.
,, Geological Society. ,, 1887.
,, Statistical Society. ,, 1887.
Manchester National Boiler Insurance Company. Chief Engineer's Report, 1886.
Midland Inst. of Mining, Civil, and Mechanical Engineers. Transactions, 1887.
Mining Institute of Scotland. Transactions, 1887.
North of England Institute of Mining and Mechanical Engineers. Transactions, 1887.

Philosophical Society of Glasgow. Proceedings, 1887.
Royal Scottish Society of Arts. 1886.
Society of Arts. Journal, 1887.
South Wales Institute of Engineers. Transactions, 1887.
Society of Engineers. List of Members, Rules, &c., 1887.
South East Coast Institution of Engineers and Shipbuilders. Transactions, 1886-7.

British Architect. From the Proprietors.
Colliery Guardian ,,
Electric Review. From the Editor.
Engineer. ,, ,,
Engineering. From the Publisher.
Gas and Water Review. From the Editor.
Gas Engineer. ,, ,,
Industries. From the Proprietors.
Invention and Inventors' Mart. From the Editor.
Iron. ,, ,,
Iron and Coal Trades' Review. ,, Proprietors.
Journal of Gas Lighting. ,, Editor.
London Iron Trades' Exchange. ,, Proprietors.
Marine Engineer. ,, Publisher.
Mechanical Progress. ,, Proprietors.
Official Journal of the Patent Office. From the Deputy Comptroller-General J. Clark Hall, Esq.

Appreciating the desirability of enlarging and improving the Library, the Council again respectfully invite the Members to make donations of books, original pamphlets, drawings, &c. To enhance the value of the Library, the Council are always willing to receive, and, if practicable, to act upon recommendations from the Members for augmenting the usefulness of this important adjunct to the Association.

Whilst congratulating the Members on the work accomplished and progress made during the past year (as epitomised in this Report), the Council see no reason why in future years the progress should not be even more satisfactory, and your Council look confidently to such a result if each Member will use his best endeavour to strengthen the influence of the Association.

OBITUARY.

J. S. Ayton served the greater part of his apprenticeship in the famous shipbuilding and engineering works of Messrs. Palmer & Co., of Jarrow-on-Tyne, and completed the same in the works of Messrs. R. Stephenson & Co., of Newcastle-on-Tyne, where he remained for some years at the close of his apprenticeship. Subsequently he was with the London, Chatham, and Dover Railway Co. for a short period, leaving there to go to Paris on his appointment as engineer and manager of the steam tramways in that city, a position which he resigned—after holding the same about two years—in favour of an offer to become manager to Mr. Henry Vignoles, C.E., of Westminster, during which appointment he superintended the laying of the North London and Suburban Tramway, and other lines. In 1882 he was appointed engineer and manager to the North Staffordshire Tramway Co., and in 1885 to a similar position to the Manchester, Bury, and Rochdale Tramway Co., with whom he was at the time of his death, which occurred on the 4th November, at the early age of 34. He was the patentee of several inventions, amongst others a self-coupling for tram engines and cars. Mr. Ayton was elected an Honorary Member of the Association in March, 1887.

John Burton was born in Liverpool on the 3rd April, 1841, and was educated at the Christ Church Schools, Hulme. He served his time as a turner in the works of Messrs. W. & J. Galloway & Sons, Knott Mill Ironworks, Manchester, and on the completion of his apprenticeship started as a journeyman turner for Messrs. Norbury & Shaw, of Salford. After an absence of only a few months, however, he returned to the works of Messrs. Galloway. In the year 1872 he was appointed foreman over fitters and turners in the light tool department—a position which he filled with great ability until the time of his death, which occurred whilst travelling by train to Chester on the 4th May. In all he was an employé with Messrs. Galloway for 30 years. He was a man of a very inventive turn of mind, and introduced many improved appliances for the manipulation of the work in his particular department. Amongt other inventions may be named a patent tool-holder for slotting and planing machines.

Mr. Burton was elected a member of the Association in 1875.

Robert Clarke was born in Ceres, County of Fife, Scotland, on the 8th of April, 1810. The third son of a family of eight sons, at an early age he was bound apprentice in the shop of a country blacksmith, named Murdoch, of Meunzie (County Fife). In 1830 he worked as a journeyman smith at Messrs. Lowe's foundry, Monifieth, near Dundee, where he stayed for about 18 months. Subsequently he worked for Mr. Carmichael, of the Ward

ications should be addressed to

8, Hullard Street,

Old Trafford,

GRAND HOTEL,

Aytoun Street,

21st February, 1888

Dear Sir,

On behalf of the Council we have pleasure in announcing that the next Meeting of this Association will be held on Saturday evening, the **25th inst.**, at the GRAND HOTEL, when Mr. LIONEL B. WELLS, C.E., of Goole, will read a paper on

"The Anderton Hydraulic Lift."

The chair will be taken punctually at 7 o'clock. Requesting the favour of your attendance,

We are,

Yours faithfully,

SAMUEL DIXON, *President.*

FRED. WALTHEW, *Secretary.*

Members will be afforded the opportunity of nominating, at this meeting, Candidates for Membership at the March election.

The following Donations to the Library will be laid on the table:

Institution of Mechanical Engineers, Transactions, September, 1887.

London Association of Foremen Engineers and Draughtsmen, Presidential Address, January, 1888.

Manchester Geological Society, Transactions, Part 13, Vol. 19.

Midland Institute of Mining, Civil and Mechanical Engineers, Transactions, December, 1887.

Engineering Journals as tabulated on cover of Association's Transactions.

THE NEW YORK
PUBLIC LIBRARY
ASTOR, LENOX AND
TILDEN FOUNDATIONS

Foundry, Dundee, for about 16 months, and Messrs. Bury, Curtis & Kennedy, Clarence Foundry, Liverpool, for about 9 months. In February, 1834, he entered the works of Messrs. Bowman & Galloway, Great Bridgewater Street, Manchester, and shortly afterwards was made foreman blacksmith. Acting under medical advice, in September, 1836, he relinquished further active employment in the smithy. Admiring the perseverance with which he adhered to his duties under failing health, the firm put him to work a planing machine, a post he filled until October, 1837. During this period his health very greatly improved, and in November of the same year he commenced work as a fitter or erector in the Locomotive shop of the Manchester and Liverpool Railway Co., at the White Gates. Here he remained until October, 1840, and during that period acquired a thorough practical knowledge, in all details, of the locomotive at rest and in motion. Subsequently he was engaged for about 12 months as a leading hand in the locomotive shop of the Lancashire and Yorkshire Railway Co, Miles Platting. In November, 1841, he again entered the employ of Messrs. Galloway (the firm having in the interim changed from Bowman & Galloway to W. & J. Galloway & Sons, Knott Mill Ironworks, Manchester), this time as a fitter. Very shortly afterwards he was appointed foreman engineer and ultimately head foreman in the works, the duties of which he discharged with remarkable ability and success and satisfaction to his employers until his retirement, through bodily infirmity, in April, 1879. He died on the 24th February, aged 77 years. As a business man he was regarded as most upright and straightforward, and all who came into intimate contact with him bear testimony of his sterling worth.

As one of the original members of the Association on its establishment in 1856, Mr. Clarke had many friends amongst the members, and his death was widely deplored. He was the first treasurer, a position which he filled with great credit till his resignation in 1867. For many years he was a regular attender at the meetings, and frequently took part in the discussions. He was instrumental in introducing to the Association a number of members, and for his many services rendered on behalf of the Association, especially during its early history, his name will be long held in grateful remembrance.

Matthew Curtis was born in Manchester in the year 1807. On the completion of his education he entered his father's business, who at that time occupied a leading position as a currier and leather dealer. In a short time however, his energies were transferred to the services of Mr. J. C. Dyer, who had recently established a business in Manchester for the manufacture of a mechanical contrivance for making the wire cards attached to cotton-carding machines, and another establishment for the construction, first of "Dyer's Frame," and then of cotton machinery in general. On the completion of his apprenticeship he was entrusted with the management of the wire-card making department. For seven years he retained this position and in 1835, on Mr. Dyer relinquishing the wire-card branch of his business, he

took over the same in partnership with Mr. Parr. Three years later the machine-making business of Mr. Dyer was also purchased by them in conjunction with Mr. Madeley. Becoming acquainted with Mr. Walton, of Sowerby Bridge, who had patented and introduced the application of india-rubber as a substitute for leather as the ground in which the wire teeth of the cards were inserted, and discerning in this application an important improvement, Messrs. Curtis & Parr took the inventor into partnership, the style of the firm being Curtis, Parr, and Walton. By 1845 the machine-making business had developed to a very marked extent, and it made such calls on time and energy as to render another evolution necessary. The wire-card manufacture was accordingly made over exclusively to Mr. Walton, and thenceforward the steady aim of the firm was to excel as machinists. The self-acting mule became the special study of Mr. Curtis, and his efforts to improve it were ably seconded by the intelligent co-operation of several of the firm's employés. At that period all other mules had practically succumbed to those invented respectively by Mr. Richard Roberts, of Manchester, and Mr. James Smith, of Deanston. The former was thought most highly of by the cotton trade, and on it was concentrated Mr. Curtis's anxious attention. Successive improvements were patented by his firm which brought this machine to a high pitch of perfection, insomuch that "Parr's Mule" became the synonym of excellence, and at once took the lead in the European and American as well as the home markets. Orders poured in apace, and the firm found it necessary to double the size of their establishment. The whole of Mr. Curtis's ingenuity was not however, expended on this particular machine; on the contrary, the science of modern cotton spinning is indebted to him for not a few efficient mechanical adaptations. In textile machinery generally the firm takes high rank. On the death of Mr. Parr and Mr. Madeley and their sons, the business devolved on Mr. Curtis, who with his two sons and Mr. Thompson—a former foreman—carried it on under the style of Curtis, Sons, and Co. The Manchester works of Messrs. Curtis are amongst the largest of the many great factories of the town, the repute of whose cotton fabrics is almost equalled by that attaching to its machine tools and machinery. The firm give employment to a fluctuating number of workpeople, ranging from 1,500 to 2,000. In the performance of his manifold public and private duties Mr. Curtis always displayed remarkable ability and great sturdiness of character, and the news of his death, which occurred on the 9th June, was received with sorrow throughout the district. He was elected Mayor of Manchester in 1860, again in 1875, and for the third time the honour was conferred upon him in November, 1886.

Mr. Curtis was elected a Life Honorary Member of the Association in 1874, and on the occasion of the 20th Anniversary Meeting and Dinner very ably filled the chair.

Edward Fletcher was born in Manchester on the 9th September, 1840, and was the third son of the late Mr. James Fletcher, of Messrs. William

Collier & Co., engineers and machine-tool makers, Salford. At the age of fourteen he was placed in the drawing office of these works, of which his father was then the sole proprietor; and in 1876 he was made a partner in the firm, along with his two younger brothers, Joseph Fletcher and David Hardman Fletcher. From 1866 to 1876 he had entire management of the foundry belonging to the firm; and since the death of his brother, David Hardman Fletcher, in 1884, he had the entire control and management of the business until his death. He was thoroughly acquainted both practically and theoretically with the manufacture of machine tools. He died on 27th June, at the age of forty-six, after a short illness.

Mr. Fletcher was enrolled an Honorary Member of this Association in 1886.

John Furnevall was born at Bury, Lancashire, on the 27th February, 1836, and was educated by Dr. Bailey, of London, then resident in Accrington. At the age of 16 he entered the works of his father at Haslingden, where he went through the shops and acquired a complete practical knowledge of the business of ironfounding. On his father's decease in March, 1859, the entire management of the business devolved upon him. The business, which had increased in importance and size considerably up to this time, was still further developed by Mr. Furnevall, and carried on very successfully by him till his death, which occurred at his residence, Rye Hill, Haslingden, on the 5th November, after a short illness. He was a Trustee of the Haslingden Mechanics' Institute, and for some years gave his services as a teacher of mechanical drawing to that Institute. He took a warm interest in all local affairs affecting the welfare of the township of Haslingden.

Mr. Furnevall was enrolled an Honorary Member of the Association in 1871.

William Griffiths was born at Edgehill, Liverpool, in 1819. He served his apprenticeship with the firm of Petrie & Co., boiler makers, of Rochdale, and afterwards worked for some time in the works of Messrs. Wood and Wildings, of Openshaw Bridge. Between the years 1839 and 1842 he worked for several eminent engineering firms in France, returning to England to enter the works of the Midland Railway Co., at Broomsgrove and Bristol. In 1850 he was appointed foreman in Locomotive department at the works of the London and North Western Railway Co. at Wolverton, where he stayed until 1864, when he undertook the management, under Mr. Gill Barber, of the Park-street Works, Manchester. In 1867 he commenced business in partnership with his brother-in-law, trading as Griffiths & Wolstenholme, at Varley Street, Miles Platting, and afterwards at Park Street, Red Bank. Through misfortune in 1873 the business was disposed of, and subsequently he held the position of foreman in several large engineering establishments in Lancashire. Failing health compelled his retirement in 1876 from further active employment.

Mr. Griffiths was elected an ordinary Member of the Association in 1866.

WILLIAM HEYWOOD was born at Prestwich, near Manchester, in the year 1808. The early part of his career was spent in the mechanics' shop of a cotton mill in Ancoats. Afterwards he was employed in the engineering works of the late Richard Roberts, then situated in Faulkner Street, Manchester. Here through steady industry and profiting by the genius of his employer, Mr. Roberts, he eventually became a foreman, in which capacity he remained till the well-known Globe Works were sold up. His first venture in business, on his own account, was in premises situated in Back Princess Street (now part of Albert Square), more suitable premises however were shortly afterwards taken in Lower Mosley Street (now part of the the Central Station). Here his business assumed a more mechanical turn, the making of tools being his chief trade. Here also he resumed a business connection with his late employer, who entrusted to him the making, amongst other machines, of a new wool and cotton combing machine as well as a cigar-making machine. How fully he satisfied the requirements of Mr. Roberts (whose exactness in everything mechanical made him a name well known throughout the country), is testified by the following letter:—

"I have pleasure in stating my conviction that the work turned out by you is not surpassed in accuracy of execution, and in some cases rarely equalled.

R. ROBERTS."

The premises in Lower Mosley Street having to be taken down he in partnership with his brother John, erected new premises in Ellesmere Street, Hulme, where the firm of W. Heywood & Co. is still carried on. Although connected with the firm at the time of his death, 4th June, for the last 12 years, through failing health and his residence being at Southport, he took little or no control in its management. Outside his own business he was always busily engaged in benevolent and educational institutions. For a number of years he was on the Board of Directors of the Manchester Mechanics' Institution. It would be difficult now to gauge the value of his intelligent and enthusiastic services in connection first with the old institution and then with the establishment of the new one in Princess Street. It may confidently be said that the success of the exhibition with which the work in the latter building was inaugurated inspired to confidence the Committee who worked out the Art Treasures Exhibition of 1857. And it is noteworthy that it was Mr. William Heywood who, 30 or 40 years ago, brought the "fairy fountain" to Manchester. He fathomed the secret of it as it was then being worked at the Polytechnic in London, set it up in Cooper Street, and for years afterwards it was the source of welcome revenue at the winter entertainments provided by the directors. He was of a singularly frank and sunny disposition, and possessed most attractive social qualities.

Mr. Heywood was elected a member of the Association in 1869. He was always anxious for its welfare and the furtherance of the purposes for which it was established.

JAMES MORAN was born in Manchester on the 7th November, 1840. In 1852 he was engaged as lodge-boy in the works of Messrs. Gadd, of Salford.

Showing an aptitude for drawing Mr. Gadd took an interest in his welfare, and he was early removed into the drawing office where he remained for several years. Having expressed a wish to go into the shops he served his time as a fitter. About the time of his completing his apprenticeship the firm was doing an extensive foreign business, and during the years 1865 to 1868 he was frequently abroad, superintending the erection of colour-printing machines, stationary engines, forcing machines, power travelling cranes, &c., &c. Subsequently he was made leading foreman in the works and eventually (1872) returned into the drawing office on his appointment as works' manager, a position which he filled with remarkable ability and honesty until July, 1884, when through failing health, attributed to overwork, he was compelled to retire after a faithful servitude of upwards of 32 years. He died on the 21st September. Possessed of a comprehensive and inventive mind he was instrumental in introducing many valuable improvements in the design and construction of the special manufactures of Messrs. Gadd.

Mr. Moran was elected a Member of the Association in 1881.

John Saxon, the eldest of four sons of the late George Saxon (himself a Member of the Association from 1864 to 1879) was born in Strangeways, near Manchester, on the 16th March, 1850, and was educated at the Openshaw National Schools. At an early age he entered his father's works, and on the termination of his apprenticeship assisted him in building up the reputation which the firm of George Saxon, Engineering Works, Openshaw, enjoys as engineers and millwrights, and since his father's decease, eight years ago, he has carried on the business in conjunction with his three brothers. He was possessed of a clear intuitive perception, which combined with extensive practical knowledge enabled him to see immediately the merits or demerits of any particular piece of engineering work. His services were often requested as witness, arbitrator and consulting engineer in cases where mechanical skill and judgment where necessary. An attack of pleurisy, the outcome of a cold contracted whilst out on business, resulted after a fortnight's illness, in his death on the 10th May, at the early age of 38.

Mr. Saxon was elected a Member of the Association in 1880.

TREASURER'S GENERAL CASH ACCOUNT, FOR YEAR ENDING 31st DECEMBER, 1887.

Dr. *(Including Superannuation Fund Account.)* **Cr.**

1887.			£ s. d.
Jan. 1.	To Balance as per last Report		2627 9 11
Dec. 31.	„ Contributions and Entrance Fees		376 0 0
	„ „ from Members (5/- each) *re* J. Moran's claim for "Sickness and Accident Allowance," under Rule 13 (£100)		10 0 0
	„ Transactions—sold		15 13 0
	„ Interest from Loans in Building Societies	£36 12 1	
	„ „ „ Mortgages on Properties	36 0 0	
	„ „ „ Stock—Salford Corporation	16 19 5	
	„ „ „ Bank	2 14 10	
			92 6 4
			3121 9 3

Audited and found correct.

M. T. CORBY,
C. O'BRIEN,
T. WOOD, } AUDITORS.

13th Aug., 1887.
14th Jan., 1888.

1887.			£ s. d
Jan. 1. to Dec. 31.	By Rent—Grand Hotel		20 0 0
	„ Secretary's Salary	£30 0 0	
	„ Assistant Secretary's Salary	10 0 0	
			40 0 0
	„ Superannuation Allowance		81 15 0
	„ Funeral Allowances:		
	„ R. Clarke	£10 0 0	
	„ W. Griffiths	10 0 0	
	„ J. Burton	10 0 0	
	„ W. Heywood	10 0 0	
	„ J. Moran	10 0 0	
			50 0 0
	„ Printing and Stationery		126 10 0
	„ Expenses, illustrating paper on "Indicator Diagrams" by the Oxy-Hydrogen Light		2 2 0
	„ Books purchased for Library, Binding, &c.		7 9 10
	„ Insurance Premium on Library		0 6 0
	„ Repairs to Library Case		0 9 2
	„ Deputations to London, Leeds, & N'castle Associations		8 5 0
	„ Thirty-first Anniversary Dinner		7 1 1
	„ Audit and Committee Expenses, Postage & Petty Cash		49 19 5
	„ India Rubber Stamp		0 14 0
	„ Office Furniture		8 16 6
	„ Loss on Investment in British Building Society		150 0 0
	„ Cash invested as Loans in B'ding Societies	£816 5 0	
	„ „ Advanced on Properties (Mortgages)	800 0 0	
	„ „ Salford Corporation Stock	500 0 0	
	„ „ in Bank	424 6 6	
	„ „ „ Treasurer's hands	18 5 8	
	„ „ „ Secretary's „	9 4 1	
			2568 1 3
			£3121 9 3

SUPERANNUATION FUND ACCOUNT, FOR YEAR ENDING 31st DECEMBER, 1887.

Dr. *(Included in General Account.)* **Cr.**

1887.		£	s.	d.	£	s.	d.
Jan. 1.	To Capital invested as per Resolution passed at the Half-yearly Meeting, 14th June, 1879 ..	2100	0	0			
	,, Additional Capital voted at the Annual Meeting, 13th December, 1884.....	300	0	0			
	,, Balance of Interest from last Report	4	1	5			
					2404	1	5
Dec. 31.	,, Twelve Months' Interest on Capital Invested as per General Account				92	6	4
					£2496	7	9

1886.		£	s.	d.	£	s.	d.
Jan. 1. to Dec. 31.	By Superannuation Allowance:—						
	Mr. C. Millward	13	5	0			
	,, R. Clarke	2	5	0			
	,, O. Williams	13	5	0			
	,, W. Mc.George	13	5	0			
	,, W. Vickers	13	5	0			
	,, J. R. Wolstenholme.....	13	5	0			
	,, E. Goodall.....	13	5	0			
					81	15	0
	,, Balance to credit of Superannuation Fund Account				2414	12	9
					£2496	7	9

Audited and found correct.

C. O'BRIEN,
T. WOOD, } AUDITORS.

14th January, 1888.

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